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SERVICING MOTION PICTURE SOUND EQUIPMENT

Books by James R. Cameron

SOUND PICTURES AND TROUBLE SHOOTERS MANUAL
MOTION PICTURE PROJECTION—5TH EDITION
QUESTIONS-ANSWERS SOUND MOTION PICTURES
MOTORS AND MOTOR GENERATORS
ELECTRICITY FOR PROJECTIONISTS
MOTION PICTURES WITH SOUND
CINEMATOGRAPHY AND TALKIES
RADIO AND TELEVISION
TEXT BOOK ON RADIO
TALKING MOVIES, ETC., ETC.

SERVICING MOTION PICTURE SOUND EQUIPMENT

BY
JAMES R. CAMERON

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TROUBLE SHOOTING

THE GREATEST aid in the possession of the projectionist relative to trouble shooting in a sound motion picture system is the various electrical meters. Yet, despite the high degree of information available from such channels, there are several vital parts of the system which are not subject to visual examination in that fashion. These are the various switches, particularly the film-disc transfer switch. It is indeed surprising to note the many hundreds of instances where complete operation ceases in a mysterious manner with much hub-bub and excitement while the actual trouble is incorrect contact in this switch. Since it controls the source of sound, imperfect contact will immediately stop the operation of the amplifier system, because a perfect amplifier and speaker circuit without a source of sound is useless.

It is bewildering to note how much trouble can be caused by the simplest of items. It seems as if the simpler the item, the less attention one pays to it and the more frequently does that item cause aggravation. We refer with particular attention to the setting of the fader potentiometer. Time and again a man will switch from one channel to another without correctly setting the fader. As a matter of fact he fails to touch the fader knob although he actually manipulates other switches adjacent to the fader control.

Of particular interest is the condition arising when a man manipulates a current or voltage control device and pays very little attention to the associated meter reading. This is an important item in connection with the exciting lamp. The Western Electric lamp operates at 3.6 am-

peres. RCA lamps operate at from 5 to 7.5 amperes, with the exact value specified upon the base of the lamp. Excessive filament brilliancy shortens tube life, whereas insufficient brilliancy materially reduces the sound output. However as a means of prolonging the operating life of the lamp, it is possible to operate below the rated filament current providing that the current consumption is consistent with good sound output.

This same condition applies to the regular vacuum tubes in the system. Meters are provided for a purpose, mainly to prevent overloading in the form of excessive steady operating potentials. However, less than normal potentials may be applied in certain cases, but they are not recommended, for the reason that an amplifier system is designed to handle a certain amount of signal and operating potentials less than normal, limit the amount of signal which may be applied, thus producing a condition conducive to distortion. Furthermore it is poor operation to continually change operating potentials because the signal voltage being passed through the amplifier is increased.

An item of importance in connection with meters is a steady indication. While it is impossible to determine complete circuit continuity by means of a meter located at one point of the circuit, it is possible to gauge conditions of voltage producing or current carrying circuits when the meter readings continually fluctuate and are unsteady. Such condition is invariably accompanied by noise of various kinds, and every effort must be made to locate the fault.

As to opens in a circuit indicated upon a meter of some kind, one should not imagine that all such defects are complicated. More often than not, the troubles are as simple as an open contact or a loose soldered joint on the terminal strip. Modern equipment considering the large tolerance values allowed are such that coils do not

burn out with great rapidity nor do condensers puncture. It is true however that the dry disc rectifiers have been known to develop a good deal of heat and eventually deteriorate sufficiently to be classed as unfit for further use.

Motors and generators, mechanical filters and such are not without their faults. While the repair of any sound apparatus in a projection room is the work of the visiting service men, investigation has shown that a great deal of latitude is allowed the projectionist in this respect.

Defective operation of generators is usually indicated by unsteady voltages manifest upon meters. In turn defective operation of motors is manifest by unsteady speed

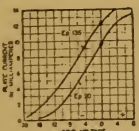


FIG. 1

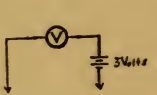


FIG. 2

of devices rotated by the motor. If these devices are allied with the source of sound, the system develops a "wow."

Visual examination of a device subject to potential such as a vacuum tube is of little utility with but one exception, namely when the tube filament or cathode does not glow or light. If however the filament is incandescent, the only method of locating the trouble is by means of a meter. The fact that the filament lights and appears to glow with normal brilliancy is not an indication of a perfect tube.

Trouble shooting in a good many cases is a matter of circuit continuity testing. The voltmeter or the current meter will indicate the presence of electric force or elec-

tric current but such indication cannot be secured unless the circuit continuity is perfect. Further the possibility of a defective meter is ever present and before one can determine that the meter is defective it is necessary to test electrically. An effective system is shown in Fig. 2. It is a simple .001 ampere high resistance voltmeter and a small 3 volt flashlight battery. The current flow through the meter is very small, 1 mil for full scale deflection, hence it is possible to test units of high resistance without injury to the unit. The voltmeter indication affords an idea of the relative resistance of the device being measured and is satisfactory for continuity measurement of practically every device, with perhaps, high fixed resistance excluded. Low D.C. resistance coils will show practical short upon the meter. Fixed condensers will show momentary charging current if perfect and constant current flow if defective. Inductances will show current flow if normal and no current flow if open.

While it is true that poor contact in a circuit will create noise of various kinds and that the location of such contacts is not limited to any one position, all defects will not become evident upon voltage and current meters. This a paramount item, for example, plate coupling resistances of the carbon type may develop noisy characteristics, yet will not cause fluctuating plate current. Then again a meter may indicate that grid voltage is present across a certain grid circuit but it will not show whether or not the winding of that transformer is perfect or shorted. An open will of course be evident since it will manifest an effect upon the plate current, but a short between turns which may be sufficient to stop completely the operation of the amplifier will have no effect upon the plate circuit since under normal conditions of no grid current, there is no drop across the grid winding of the transformer.

It might be well at this time to state with emphasis

that continuity tests should not be made with the amplifier power circuit "on." Unpleasant shocks are liable with very annoying after effects. Further, accidental handling of test equipment may cause damage to some of the equipment.

The projectionist confronted with trouble and without emergency equipment, is in a sad predicament, particularly if he is not very familiar with the apparatus. Yet some of the simplest measures may prove to be most effective. The fact that a filament voltmeter or a plate current milliammeter indicates circuit continuity and normal circuit continuity, does not mean that all the tube prongs are making good contact with the sockets. A slight jar may be sufficient to dislodge one contact. One should always remember that the smallest separation between two contacts which will not allow the flow of current is no better than a separation of several feet. The smallest "open" is nevertheless an "open." Hence a few moments spent to ascertain if the tubes are well lodged in the sockets might prove very beneficial.

One need not be a technician to realize that innumerable defects may occur in a sound motion picture system. It is possible however to lay stress upon certain special units, particularly those which are manipulated most frequently and those which do not indicate a visible manifestation. Pick any amplifier you choose. The switches are vulnerable items, only because spring contacts eventually lose their resiliency. When that state arises, then the switch is defective and while it will make contact, the junction is not secure.

When one speaks of switches it is customary to think of the control switches located in the various power circuits. These switches are not the only offenders. The small snap switches whereby speakers are changed from one circuit to another are often the sources of annoying trouble. One believes that the contact is perfect because

the switch lever is in the proper position. However the perfect contact is that which wipes a clean surface as it moves across the studs. All of this comment does not apply to only one type of installation. Each and every amplifier is subject to such complaints and this is true regardless of the price paid for the equipment.

Investigation discloses that the majority of sound systems are designed with a wide degree of tolerance insofar as the operating voltage of the respective units is concerned. As a result filter condensers and filter chokes give very little trouble, but trouble can be created by operating amplifiers without the regular loads.

Of course the operating characteristic of a generator voltage supply source is such that a part of the load may be removed without a radical change in the other voltages. Battery eliminators however do not perform in similar manner. When the load is removed the voltage increases and causes additional current flow, perhaps excessive current flow for any one particular resistance. The resistance develops a defect. The same is true of tubes, excessive operating potential due to insufficient load upon the eliminator may so increase the voltage upon the tubes that gas develops and finally renders the tube unfit for use. As a simple precautionary measure we suggest that tubes be operated at normal voltage by not changing the load without cutting off or turning off the power supply. We of course realize that at certain times, tube filaments burn out and operation at reduced current load is maintained, but such conditions cannot be helped.

While it is true that certain parts of a sound picture system are actually more vulnerable than others because the apparatus is more sensitive, one should not always believe that in the event of failure that that part has "gone west." The most rugged units will fail and the surest method of failure is an overload.

As a suggestion which has been found advantageous in

actual practice, we suggest a checkup of all fuses after each major failure. No matter what is being done, amplifiers which indicate that some part has failed should not be operated for any length of time in that condition. The fact that the filament of a tube appears to have been extinguished does not always signify that the tube filament has burned out. In some cases short circuits develop and unless detected immediately may cause permanent injury to an expensive piece of equipment.

It is difficult to outline the possible troubles which may occur in all systems because of the dissimilarity between the respective systems. For example Western Electric apparatus of certain type may be equipped with resistance pads or attenuators. These devices are located in the fader control box. While it is true that the current flow in such circuits is very small, the possibility of trouble is present nevertheless.

Quite naturally those pads which are subject to the maximum current flow and are manipulated most frequently will fail first, but bear in mind that nothing is immune. One of the greatest fallacies is that a circuit without moving parts is not subject to breakdowns. Grounds, shorts and opens may occur in all circuits.

Somehow or other we feel and we have found it to be so in practice, that systematic inspection while tedious upon the surface is actually the best preventative against major troubles. Particular reference is being made to mechanical parts which are in motion during projection. Now, we do not wish to devote much space on the maintenance of projection machinery, but loose parts or units which just do not mesh exactly as they should are worthy of immediate and detailed investigation. As to the investigation, the actual work is up to the projectionist.

The fact that equipment is new means nothing. Defects may have developed during transit, trouble may develop immediately after the installation men and the

inspection department have accorded their approval. Of course such conditions are not frequently met with, but the possibility is there nevertheless.

One cannot leave the subject of moving machinery, particularly rotating machinery without covering the subject of lubrication. Lubrication is an important item and more than one service man has been called to repair a frozen machine due to lack of proper lubrication. On the other hand excessive lubrication has its disadvantages. Too much lubrication, while perhaps not as bad as insufficient lubrication will also cause aggravating difficulties. The oil will overflow and dirty other parts of the machine, and should oil reach the sound track on the film, poor reproduction will result.

As a matter of fact too much oil in rotating machinery such as motors will actually cause grief because it will lodge in the commutators and cause sparking. Cleanliness is a paramount virtue. Anything allied with the electrical if allowed to accumulate dirt will give trouble. This applies in particular to switches, rotating parts of motors and spaces between electrical junctions. The amount of power present in a sound motion picture system is by no means excessive and none can be wasted. Dirt will cause leakage. Corrosion will not only cause bad contacts but will eventually eat away the junction.

Vacuum tubes should be kept in cartons so that oxidization cannot set in upon the prongs. If such condition is allowed to exist the contact between the new tube and the socket will be very poor. All equipment should be cleaned daily. Lint and moisture if allowed to settle upon condenser terminals will provide leakage paths which will arc during operation giving rise to noises of various kinds.

Relative to testing, we have but few suggestions. The projectionist who reads these pages has supplementary data pertaining to the amplifier at hand, i.e., data stat-

ing the exact operating conditions. Our only suggestion is that he make certain that the current and voltage values are exactly as specified. Investigation is necessary when the existing values approach the stated minimum values. But under all circumstances make certain that all contacts are closed. We do not believe in the word "flip" or "snap" as applied to controls or switches. Switches should be "set" and set positively without any guesswork.

Electrical circuits do not possess the characteristics of convalescing patients. Normal operating values should obtain within at least 1 minute after the "juice" is connected. If meters act sluggish, investigation is in order. Perhaps the defect is minor, being imperfect alignment of the meter pointer which will not influence the operation of the amplifier, but even then the meter is the visual guide and it should be perfect in every respect.

A perfect amplifier system should not display peculiar operating characteristics during the first few minutes of operation. Quiet operation should prevail from the moment the power switch is set until the amplifier is turned off for the day. Any and every form of noise should be investigated. It is difficult to hazard the position of the defective element and its location may be such that at some future time, perhaps in the midst of a program, some element will "blow" interrupting the program and perhaps carrying with it some other part of the installation.

Substitution in the event of a failure should be made by only a new identical part. However, one cannot be expected to carry a complete set of replacement units if an emergency amplifier or channel is not available, but at least two spare tubes for every tube used in the amplifier should be available. In the event that three or four power amplifier circuits are used in parallel and one tube blows, do not use the amplifier with the blown

tube, unless it is necessary in order to secure the correct volume. In the majority of cases, emergency operation is possible with only one power amplifier and the gain control set to a higher output. The reason for the above is that the remaining tube in that amplifier is being subject to an overload voltage and the various parts of that amplifier are being subject to excessive current flow with excellent possibilities of irreparable damage. We note suggestions to check operating voltages at the start of the show. Such voltages if possible, should be checked several times during the day. As a matter of fact the plate current meter should be in the circuit at all times and particular care taken to observe the action of this meter needle. It should remain stationary at the correct plate current value during operation. If it fluctuates, something is wrong, even if distortion is not evident in the reproduced sound.

Trouble shooting in any system must be a process of elimination no matter how elementary the procedure. The reason for this is that the only visual guides, meters, no matter how great the efficiency cannot indicate certain important defects. Isolation of the units employed in a complete amplifier is the only logical method of procedure. We are fully aware that certain definite steps are recommended, but an analysis of these suggestions carries one from one part of the system to the other and wholly omits the amplifier proper.

SERVICING SOUND EQUIPMENT

IT HAS been the policy of leading sound equipment manufacturers to sell routine service with their reproducing equipment. While there are a number of good reasons for the adoption of such a policy, its justification has not always been made clear to the exhibitors. As a result, routine service has been a subject of considerable discussion among exhibitors since the introduction of sound into motion pictures. However, before entering into a detailed discussion of the service tools and methods employed, it will be well worth while to review the reasons for the extreme care exercised by the sound equipment manufacturers in the selection and equipment of their service personnel.

The entertainment field today, as in the case of other industries, is in a highly competitive state. This applies not only to the relations between equipment manufacturers, but also to those existing between theaters, producers, and various fields of entertainment. Under these circumstances, the public reaction to a picture affects more than the financial returns to the exhibitor. Each picture adds or detracts from the score, which in its cumulative effect spells the success or failure of producers, distributors, and equipment manufacturers. Therefore, nothing can be overlooked that may in any way detract from a full enjoyment of a screen presentation. Aside from its artistry and technic, the picture must be well photographed and the sound accompaniment must be of high quality, both in rendition and recording. With all the necessary qualifications, however, a film

production may still give poor results when used in reproducing equipment that either is not up to modern standards of quality or is in a poor state of maintenance. Recognizing the effect of individual performances on the sound motion picture industry as a whole, it is therefore not surprising to find that equipment manufacturers are making every effort to organize a well-equipped service force to maintain the equipment in the best possible operating condition.

The problem of maintenance when referred to sound equipment consists of two main features: (1) the prevention of sound outages, (2) the maintenance of the quality of reproduction that is normal for the equipment. Given a sound equipment in which the component parts are of good manufacture and have an adequate factor of safety, the problem of prevention of sound outage revolves itself into a periodic check of the parts that wear or deteriorate with use and must be replaced before they cause trouble. The maintenance of the normal quality of reproduction, on the other hand, requires a careful check and possible readjustment of various components of the equipment that influence the quality of the output. For the past three years, manufacturers of sound equipment have been making efforts to simplify their equipment and to reduce such adjustments to a minimum. While there has been continued progress in this direction, there are still a number of adjustments that require special tools and specially trained men. It is the purpose of this chapter first to outline briefly the parts of the equipment that are the most likely to cause trouble, and then to study in detail the servicing methods employed in checking, correcting, and adjusting them.

In discussing the problem of maintaining sound installations, it is convenient to divide the equipment into three main subdivisions: (1) The sound head, (2) The amplifier and control panels, (3) the speaker. Of the

three groups, the sound head requires the most attention, and is the most exacting in its adjustments. The condition and adjustment of every mechanical unit used in the constant motion of the field in front of the light beam affects the quality of the sound, and every part of the optical system that may affect the size, position, and intensity of the light beam influences the volume and the quality of the reproduction. Of the various components,

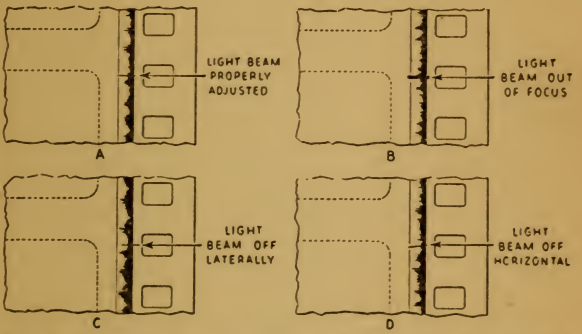


FIG. 3—Diagrammatic representation of the various positions of the light beam with reference to the sound track

the condition of the constant-speed sprocket and the adjustment of the sound gate assembly are the most critical. Unless the film moves at an absolutely uniform speed through the gate, the resultant sound will have what is termed a sprocket or gate "flutter," the exact designation depending upon the cause of the flutter. The presence of such a flutter is usually evidenced by a characteristic rasping noise, which is particularly noticeable at the higher frequencies. Where this condition exists, the trouble may be due to excessively worn sprocket

teeth, the use of a constant-speed sprocket of incorrect diameter, or to the lack of the necessary tension in the springs of the pressure gate. The adjustment of these springs is quite critical. If the tension of the spring is inadequate, there will not be a sufficient "drag" or "hold-back" on the film, with consequent gate flutter. On the other hand, if the tension is excessive, there will be abnormal wearing of the teeth of the constant-speed sprocket, with a decided tendency to "hook."

The adjustment of the light beam passing from the exciter lamp to the sound track has a material bearing on the quality of reproduction. Fig. 3 represents diagrammatically the various positions of the light beam with reference to the sound track. Fig. 3 (*A*) shows the position of the light beam when properly adjusted in reference to the sound track. Fig. 3 (*B*) illustrates the case where the light beam has the proper lateral adjustment but has not been properly focused. In the case of Fig. 3 (*C*) the light beam does not have the proper lateral adjustment, so that it does not scan the entire width of the sound track. In Fig. 3 (*D*) the light beam is properly focussed and has the proper lateral adjustment, but the light slit is not horizontal. In all the last three cases, distortion in one form or another will be introduced, with a consequent loss in the quality of reproduction. To maintain the normal high standard of reproduction, it is essential that the service engineer carefully check the adjustment of the light beam on his periodic visits to the theater, and to make the necessary readjustments in accordance with the methods to be described.

Other maintenance items on the sound head are exciter lamps and photoelectric cells Exciter lamps, in particular, deteriorate with use, and have to be replaced frequently. As their replacement and adjustment in the socket is a comparatively simple process, however, they

are rarely the cause of annoyance. In addition, there is the possibility of obtaining poor sound quality or of sound outage due to excessive wearing of gears and drive chains and loosening of belts.

Compared with the sound head, amplifiers present an easy problem to the maintenance man. Tubes, and rectifier stacks or batteries, where used, are the only items that deteriorate materially with use, and should be inspected periodically to avoid possible sound outage or deterioration in quality. Recent improvements in rectifier stacks have rendered these units quite reliable and have prolonged their life, so that no trouble should be expected from them until the equipment has been in service for several years. As they approach the end of their useful life, however, there is a gradual increase in the reverse current and in the internal resistance, with a consequent loss in efficiency of rectification. At this stage, the stack should either be replaced or kept under close surveillance to avoid sound outage.

Batteries have always been considered a reliable source of direct current. It is rather difficult to give an accurate estimate of the life of a storage battery since the life is so materially affected by the number of hours it is used daily, the rates of charge aand discharge, and the general care given by the projectionist. Regardless of this fact, however, a battery should not be a source of anxiety in view of the fact that it invariably gives adequate advance indication of approaching failure. These danger signals consist of its inability to hold a charge and the necessity of frequent charging to maintain the proper voltage.

Various component parts of the amplifier are, of course, subject to failure. Such failures are, however, infrequent, and cannot be predicted to forestall a possible sound outage. The maintenance man's only recourse is to see that the various amplifier units are kept reasonably free from dirt and dust, particularly in the section

between exposed wires or terminals, and periodically to ascertain that none of the power transformers or condensers are heating excessively.

We now come to the question of speaker maintenance, which presents an even simpler problem than the amplifier. Assuming that the stage speaker has been properly installed behind the sound screen, there is very little likelihood of difficulty from this source unless someone tampers with the unit. The service engineer, however, generally makes it a point to listen carefully to the reproduction from the stage speaker to discover rattles or distortion that may have developed since his last visit to the theater. Where such trouble is definitely traced to the loud speaker, it is usually found to be due to a loose wire or to a lateral displacement of the speaker cone, allowing the voice coils to rub against the sides of the field air gap.

The sound screen, behind which the speaker is located, frequently presents a maintenance problem, particularly if it is of the porous variety. The pores of such a screen accumulate dust, and, unless the screen be cleaned periodically, there will be a gradual loss in sound and deterioration in quality. Where such difficulty is experienced, the question as to whether the screen is at fault can be definitely decided by comparing the volume and the quality of the speaker output with the screen in place, and with the screen "flown" or removed.

The foregoing outline briefly covers some of the main problems encountered in the maintenance of theater sound equipment. It indicates the parts of the equipment that must be kept under surveillance or checked periodically to prevent sound outage and to obtain the best possible sound quality and service from the equipment. On their periodic visits to the theater to make such inspections, the service engineers encounter some difficulty due to limitations of working time and of space in which they

must perform their tests. As there can be no interruption of the performance, practically all the checking operations have to be performed either before or after it. This of course, means additional expense for the exhibitor. Therefore, to keep overtime to a minimum, the work must be performed as rapidly as possible, and, because of the limited space in the average projection booth, it must be done with as few instruments as possible. These two factors, as well as the obvious one of reasonable accuracy, must naturally be taken into account in designing test equipment to be used in maintaining sound equipment.

The RCA Photophone service engineer's test equipment consists essentially of a tool kit, a multitester or set analyzer, and a test reel.

There is very little of special interest in the service engineer's tool kit. It contains a complete set of tools for installing and servicing sound heads and amplifiers. In addition to items such as hammers, screw drivers, files, wrenches, pliers, *etc.,* the kit is furnished with a relay adjusting tool, a relay contact cleaner, special size socket wrenches, a taper-pin pusher, a gear remover, a circuit tester, and a special optical adjusting tool. The use of the last item will be described in connection with the use of the test film.

The KR-13 multitester, specially designed for RCA Photophone, embodies in a compact form all the meters and special testing devices needed in sound equipment work. The various meters, with the necessary shunts and multipliers, will measure direct currents from 1 microampere to 75 amperes, d-c. voltages from 0.1 to 750 and a-c. voltages from 1 to 250. By means of a plug that may be inserted in the various amplifier sockets, tube and amplifier measurements may be made under conditions simulating those of normal operation. A microammeter, with a range of 15 microamperes, is used for

checking photoelectric cells and for making measurements of high resistance.

In addition to the above, the KR-13 multitester is provided with special binding posts for making "continuity" tests and for phasing speakers. A thermal output meter, in conjunction with the RCA Photophone test film, is used for making frequency response measurements and optical system adjustments.

The standard RCA Photophone test film is used as a source of signal output for making practically all the necessary measurements and adjustments of sound equipment. The film is approximately 1000 feet long and has a sound track on each edge. It is so recorded that it is unnecessary to rewind the film to play the track on the opposite edge of the film. The recording on one edge of the film includes 140 feet of "buzz" track, 200 feet of 9000-cycle parallel line track, 100 feet of 1000 cycles followed by a constant voltage frequency test track varying, in equal steps, from 50 cycles to 6000 cycles.

Fig. 4 represents an enlarged facsimile of the so-called "buzz" track. Essentially, it consists of two chopper tracks, each 10 mils wide, spaced 90 mils apart. The chopper track nearest the sprocket hole is a 300-cycle record, and the other chopper track is a 700-cycle record.

The track is designed to make the lateral optical system adjustment and to determine the extent of film "weave" in the sound gate by a listening test, without the aid of eyepieces or reflecting mirrors. When the film is properly adjusted in the sound gate, the light beam from the exciter lamp will fall between the two chopper tracks, and there will be no signal output from the stage speakers. When, on the other hand, the light beam is off to one side or the other, as illustrated in Fig. 4 (*B*), a constant note will be reproduced in the speakers, the frequency and volume of which will depend on the extent and the direction in which the film is off. If the

note heard is of 300-cycle frequency, the film guides should be adjusted to move the film outward; if the 700-cycle note is heard, the film guides must be adjusted to move the film further in. Occasionally, due to a warped film or a maladjustment of the gate tension springs, difficulty will be experienced through film "weave." Such a condition will be indicated by the reproduction in the speakers of a 300- and a 700-cycle note alternately, the extent and frequency of the weave corresponding to the volume of the signal and the frequency of the alterations, respectively.

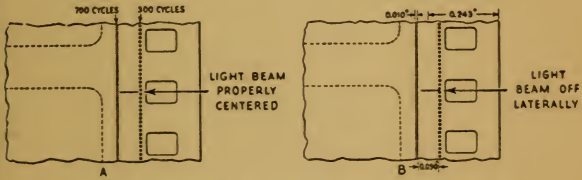


FIG. 4—Enlarged facsimile of the "buzz" track

Having centered the light beam on the sound track by means of the "buzz" track, as described above, the 9000-cycle parallel line track is used for making the rotational and focal adjustments of the optical system. This track consists of a series of parallel lines, each 70 mils long and 1 mil wide, spaced 1 mil apart. Fig. 5 shows enlarged diagrams of the 9000-cycle parallel line track: (*A*) shows the case where the light beam has not been properly focused on the sound track; (*B*) shows the case where the rotational adjustment is incorrect; that is, the light beam is not horizontal; (*C*) shows the case where both the focal and the rotational adjustments have been properly made to obtain maximum response. It is obvious from these diagrams, and the theory of repro-

duction from film, that the maximum signal will be obtained from the sound track when the light beam is sharply focused to a width of 1 mil or less, and is absolutely parallel to the lines on the sound track.

In making the adjustment, the thermal output meter on the multitester is connected across the speaker terminals of the power amplifier, with a resistor load substituted for the speaker voice coil. With the 9000-cycle parallel line track running through the sound gate, the focal adjustment of the optical system is gradually varied, and the reading of the output meter is observed. As the light beam becomes more and more concentrated, the output of the amplifier is gradually increased until perfect focus is attained. If the adjusting screw is turned beyond this point, the readings of the output meter will pass through a maximum and start to decrease. The adjusting screw should then be turned back until the peak is reached, at which point the set screw must be tightened.

In the later type of optical systems, the light slit is fixed with reference to the machined base of the optical unit, so that no adjustment is necessary. On the older units, however, the light slit is movable, so that a rotational adjustment is necessary to obtain maximum output from a given sound track and to avoid distortion. This adjustment is effected by using the same tools and methods employed in making the focal adjustment. With a 9000-cycle parallel line track running through the gate, the aperture plate is rocked back and forth by means of a vernier extension rod until maximum reading is obtained on the output meter, at which point the plate is then fixed by tightening the set screw. By the use of this method, the light beam may be adjusted to within one-half a degree of the horizontal lines on the sound track.

The frequency test track, which follows the 9000-cycle

parallel line track, is used to obtain overall output characteristic curves for the sound head and amplifier. The output response obtained in this way could be calibrated so that the curve may be plotted in volts, in decibels, or as a percentage of output at a given frequency. In the case of the multitester, it is found convenient to plot output curves as a percentage of the output voltage at 1000 cycles.

The frequency test track is also useful for locating the causes of rattling or buzzing of speakers. Among the various frequencies included in the frequency track, there will be one that will correspond to the natural frequency of the loose wire or part, so that it will start to vibrate. The faulty element, having thus been located, may then be tightened or adjusted.

The foregoing covers the description and uses of the recording on one edge of the standard test film. On the other edge of the film is a series of recordings of various musical instruments, and masculine and feminine voices, each section of the track being a special test for some particular characteristic of the equipment. The first in line is a piano solo track expressly intended for checking and determining by ear, the extent of "wows" in the reproduced sound. The composition of this piano solo includes sustained notes that exaggerate the "wows" in reproducing equipment. All the necessary adjustments for the elimination of "wows" and "flutters" is performed during the playing of this selection.

A flute solo follows the piano solo. This recording may be used in a listening test as a check to determine the adjustment of the optical system, and the possible presence of sprocket "flutter." It may also be used to locate loose metal or wooden parts in the vicinity of the stage loud speaker that may vibrate in sympathy with reproduced sound.

The flute solo has an abundance of slurred notes in the

high frequency range. In the listening test, a lack of brilliance, crispness, or definition, particularly in the higher frequency range, will indicate that the optical system is out of adjustment. Sprocket "flutter" or improper gate and optical system adjustments are indicated by a "fuzziness" of the high frequency notes.

Two violin selections and one cello selection are next. One violin selection is a standard RCA Photophone variable width recording; the other is recorded with RCA

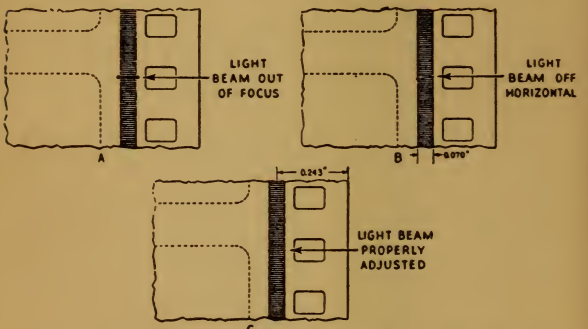


FIG. 5—Enlarged diagrams of the 9000-cycle parallel line track

Photophone anti-ground noise track. These selections are used to determine, by ear, the frequency balance; using the cello to check the response at the low frequencies, the standard variable area muted violin record to check the middle range, and the anti-ground noise violin record, as well as the flute record, to check the upper range.

Vocal solos and dialog are next; these are used to check for intelligibility, clarity, and naturalness of reproduction. They provide a good test for the middle

range of frequencies, which have the greatest influence on the intelligibility of speech.

The above outline briefly covers the standard methods employed today in testing and maintaining sound equipment. In the present state of the art, it is difficult to predict the outcome of the present trends in the design of sound equipment. Manufacturers recognize the desirability and are striving for further simplification of the equipment. At the same time, there will have to be a decided improvement in the standards of sound quality to meet the demands of a public that is becoming more and more discriminating; and instead of eliminating adjustments, it may be necessary to add to them or to refine the present test methods to meet the new standards. For the present, at least, it goes without saying that any sound system, the servicing of which does not include meticulous care and complete periodic checks with adequate instruments will not, week in and week out, give the high quality of reproduction increasingly demanded by the theater-going public.

ELECTRICAL MEASURING INSTRUMENTS

THE purpose of this chapter is to describe the tests and electrical measuring instruments which are used in the operation and servicing of sound equipment for motion pictures with the idea of helping those who use this equipment.

The tests and instruments may be divided into two groups as follows:

1. Tests and instruments used with the equipment while in operation.

2. Tests and instruments used in locating trouble, making corrections or adjustments between operating periods.

Tests and Instruments Used During Operation— While the equipment is functioning properly everything reasonably possible should be done to maintain this condition. One essential is to have perfect spare parts ready to be put to use at the first sign of trouble, among these would be at least one spare pickup, light sensitive cell, exciter lamp, each type of vacuum tube, or even a spare amplifier to be switched into service is not out of place.

However, the time to bring these spare parts into service is determined to a great extent by electrical measurements. As a great proportion of the equipment is provided with jacks for head phone tests these should be a part of every projection equipment.

Exciter Lamp—This may be controlled by the voltage across the filament or the current flowing through it, as determined by the manufacturer. If by current, the ammeter or milliammeter should have a low resistance which will not only consume little energy but alter the

total resistance of the circuit as little as possible. Since the light emitted from most lamps is quite sensitive to current changes the accuracy should be high. The instrument should not show errors exceeding 2%. If the voltage across the filament is to be observed, the voltmeter should have a high resistance so as to measure, but not alter the voltage applied. It has been found satisfactory to use a resistance of 60 ohms per volt, but, where the filaments require small currents even higher values are desirable.

When the filament has sagged too much or the bulb has begun to darken, so that it requires more current to give the same light, it should be replaced.

Light Sensitive Cell—Except for substituting a spare cell, practically no test can be made on this device by the projectionist. One crude test that may be used is to operate a good exciter lamp with alternating current and then with head phones test for sound at this frequency. Otherwise have the suspected cell tested by the manufacturer or a laboratory with suitable photometric equipment.

Film Pick-Up Amplifier—As this device employs vacuum tubes it is necessary to use some means other than the head phones to effectively determine when the tubes need to be replaced and to assist in operating them as directed by the manufacturer. The following are some of the methods used.

Here, as with the exciter lamp, the filament should be operated at a definite current or voltage as determined by the manufacturer.

Where the filament of the film pick-up amplifier is supplied with A.C. similar measurements may be made with a movable iron type of alternating current instrument and its deflections are proportional to the square of the current through its field coil. It indicates the root mean square value of the current through its field coil

or the voltage applied to the terminals. These instruments are used as milliammeters, ammeters or voltmeters and are correct to 1% of the full scale value.

The value of voltage applied to the grids of the vacuum tubes is quite important. A check of this voltage is made with a direct current instrument. It is desirable to use a high sensitivity voltmeter for this test such as 1000 ohms per volt and in some instances, due to the nature of the circuit, the readings will be an approximation of the grid voltage.

The voltage as applied to the plates of the vacuum tubes is also important and should be maintained at a value as directed by the manufacturer. This measurement may be made with an instrument with suitable range and it is desirable to have a sensitivity of at least 1,000 ohms per volt. This instrument will also be an indicator as to whether the rectifier circuits are operating properly.

The above instruments as stated are used in obtaining the correct operating conditions for the vacuum tubes, but to determine when a tube should be replaced it is found useful to measure the plate current. This measurement is made with a direct current, permanent magnet movable coil, milliammeter of suitable range connected with or without jacks so as to measure the current in each vacuum tube plate circuit. This instrument is a milliammeter.

This instrument serves a number of purposes. The manufacturer of the equipment usually states or has marked on the scale of the milliammeter the limits between which the plate current should come. If the current is outside these limits at the installation there may be wrong values applied to the filament, plate or grid of the tube or the tube itself may be defective. After proper adjustments have been made and the equipment has been put into operation should this plate current fall outside

the limit, the tube should be replaced. However, if a new tube, which is known to be normal, is inserted and the plate current is still outside the limits, the filament, grid and plate voltages should be checked up, so that watching the plate current milliammeter will be a check on the other equipment as well as to tell when to replace a tube. The indication of the plate current milliammeter should be steady. Any variation of this deflection with the modulation is an indication of distortion and should be corrected.

A direct current, permanent magnet movable coil milliammeter is often used in the grid circuit to detect the presence of any grid current. Should a current be detected it is an indication of distortion and steps should be taken to check up the plate and grid voltage of the vacuum tube.

Plate Voltage Supply—When the filaments of the rectifier tubes are supplied from the same transformer as supplies the filament of the amplifier, even though a separate winding is used, the voltmeter of the amplifier is a check as to the correct filament voltage for the rectifier filaments. Also the plate voltmeter of the amplifier is a check as to the output of the rectifier tubes.

Intermediary and Power Amplifiers—Instruments similar to those used for the Film Pick-Up Amplifier are used, with ranges which are selected to suit the tubes. When tubes are connected push-pull they should be matched. One indication of this is the plate current and this should be watched. These currents should be alike within about 12% and when this difference becomes greater than this, one or both tubes should be replaced. Having a milliammeter in each tube plate circuit or having means for switching the milliammeter from one tube circuit to the other saves much time in determining which tube needs replacing.

Storage Batteries—It is very important to know the

charge and discharge currents of the storage batteries and for this purpose an instrument should be used having suitable ranges with the zero at the center or at any other position so as to show discharge or charge.

The voltage of a pilot cell should be observed as the voltage per cell should not drop lower than 1.7 volts nor should the charge be carried beyond the point where the voltage per cell is more than 2.7 volts.

For this measurement it is desirable to use a hand calibrated instrument having suitable range.

Arc Lamp—Direct current or rectified A.C. is generally used for the arc lamp so that a D.C. ammeter should be used.

With the advent of motion pictures with sound, speed has taken on a new meaning, that is, it must be maintained at the speed at which it is recorded and not any arbitrary value. This film speed is generally 90 feet per minute. In order to secure this, various means are employed such as synchronous motors with and without tuned control circuits. However, there are still uses for some form of speed measuring instruments.

There are certain general conditions which must be met by a speed measuring instrument or tachometer.

1. It must be light in weight and compact. This is especially important for portable equipment such as cameras.

2. It must be reliable and require practically no attention.

3. The accuracy must remain constant and must not be affected by wear of its mechanical parts.

4. A small amount of power should be required to drive it. This is quite important, for some equipment very little power for the magneto is available.

5. It should be possible to observe these speed measurements at points remote from the machine under test. In addition to an indication in the projection room it has

been found desirable to have this speed indication available for the orchestra leader, the theater manager and possibly the box office.

These requirements are obtained with the electric type. Among the forms of electric tachometers those generating a potential of about 3 to 6 volts per 1,000 revolutions per minute are most practical for the motion picture field.

This electric type consists of a direct current generator having a permanent magnet field, a revolving armature provided with a commutator from which the brushes collect the generated current. With this are indicating electrical instruments connected with suitable cables.

Tests and Instruments for Locating Trouble, Making Corrections or Adjustments—It is necessary at times, even though the apparatus is equipped with instruments permanently wired and mounted, to provide some servicing equipment in case of improper functioning of the circuit. It may be necessary to make a few simple adjustments or even to check the instruments used for operating.

A service or test set should embody certain tests and instruments.

Means should be provided to measure the:

Filament voltage.

Plate voltage.

Grid voltage.

Plate current for normal grid potential, and some other value of grid potential.

Plate current of half wave rectifier tubes and both plate currents of full wave rectifier tubes.

Line voltage and transformer secondary voltage.

All the above should be possible while the apparatus is operating.

This would, beside determining the operating condi-

tion of each tube, also be a check of the instruments permanently mounted.

In addition, the service test set should provide means for testing the continuity of circuits and wiring, make measurements of voltages A.C. or D.C., measure resistance, and capacity.

The A.C. voltmeter has ranges of 750/150/16/8/4 volts arranged with a selector switch for the 4/8/16 volt ranges so as to measure filament voltages. These ranges and the 750/150 are also brought out to separate binding posts. The instrument is calibrated to read root mean square values and has an accuracy of 2% of the full scale value. The 750 and 150 volt ranges require approximately 15 milliamperes for the full scale deflection and the 4/8/16 volt ranges require 100 milliamperes. This design makes it possible to obtain good characteristics on all ranges. The 750/150 ranges are electrically insulated from the 16/8/4 volt ranges.

The D.C. voltmeter has ranges of 750/250/100/50/10/5 volts and 100/5 milliamperes. When used as a voltmeter, the resistance is 1,000 ohms per volt. A selector switch is arranged to utilize these ranges to test the voltages and currents at the tube socket and is also provided with binding posts so that the voltmeter may be used with test cables provided with the tester. This instrument is for D.C. only and is calibrated for average values with an accuracy of 2% of the full scale value. A direct current milliammeter is also provided having ranges of 100/20 milliamperes available for the tube under test or by means of binding posts.

The test set is also provided with a self-contained battery and the test cables for making continuity tests. These may be used with a table furnished to measure resistance. Values of resistances from 20 to 100,000 ohms may be measured.

These continuity or resistance tests should be made

with all power disconnected from the circuit under test.

The continuity and resistance tests may be used to test loud speakers and their circuits. The resistance values of the voice and field coil may be obtained from the manufacturer. A test between voice coil and field circuit may be made.

Means are provided in this tester to apply the normal value of filament voltage, and with 110 volts A.C. applied to the plate by connection to an ordinary A.C. lighting socket, the grid potential is changed so as to produce two values of plate current. A milliammeter is provided to measure these currents and a chart is supplied showing the average values as taken from a large number of good tubes.

VACUUM TUBES

To disseminate information pertaining to sound motion picture service work is a lengthy procedure. Not necessarily tedious—but lengthy. In view of the fact that a little knowledge is dangerous, we believe that a detailed analysis will serve better than a cursory explanation of the details involved.

Service data associated with any part of the amplifier involves the vacuum tube, since this tube is a part of each system and its operation is controlled by the condition of the various systems, including the power supply units and circuit continuity. Now, we wish to make clear that we are not attempting an elementary course in vacuum tube design. We recognize fully that some of the information contained in these pages is known to some of the readers, but we are also certain that some of the data supposedly known is not fully comprehended. Hence, we move along this line of progress, and by discussing vacuum tubes at this time we eliminate the need for further discussion as we progress through trouble diagnosis and isolation.

We take for granted that the reader is familiar with the structure of the conventional type of three-element vacuum tube, and to a certain extent with the function of the various elements. We will dwell to a certain extent upon the latter in a manner somewhat different than the conventional.

Vacuum Tube Tests—Sound picture amplifier servicing, to be satisfactory, requires the most rigid form of work consistent with accuracy and the attainment of results. With this in mind, one cannot help but wonder

about the most suitable test for a vacuum tube to show its condition and to prophesy its degree of performance. In this connection, we must realize two conditions: first, the tube which is new and second, the tube which has been in use for a period of time.

The average vacuum tube has four important constants: electronic emission, plate impedance, amplification constant (mu) and the mutual conductance. Now, it is quite logical that a rapid test of the vacuum tube need not involve the determination of all of these constants, particularly if the tube is new. The same is true if the tube is removed from a defective amplifier. The reason for this is that these constants are governed by one major element, the condition of the filament. If the filament is intact and in perfect condition, and if the physical structure of the tube elements has not been altered, the various electrical constants will be as decided upon in the design. If, however, the most vulnerable part of the tube—the filament—has undergone some change, it will influence some of the electrical constants of the tube, since the value of the constant is governed by the number of electrons emitted by the filament. By this we do not wish to imply that the design of the filament governs the constants. What we mean to say is that the electronic emission from the filament exerts a tremendous influence upon the two most important tube characteristics; the plate impedance and the mutual conductance. The amplification constant remains uniform over a very wide range of filament temperature and electronic emissivity. Therefore, as a rapid test, the electronic emission is as good as any, assuming no physical damage to the tube.

As an illustration of the above, the amplification constant of the average 226-type tube remains between 8.2 and 8.4 over a filament potential range from .5 to 1.7 volts, whereas the plate impedance is approximately 43,-

000 ohms at .75 volt and 8,000 ohms at 1.5 volts—and the mutual conductance is approximately 250 micro-ohms at 1.5 volts on the filament.

Electronic Emission—The importance of satisfactory electronic emission is self-evident. With respect to the test of a tube removed from an amplifier, the paramount test is that for electronic emission, bearing in mind that the tube has been in use for a period of time, rendered satisfactory service during that time, and that the physical structure of the tube does not undergo a change, unless of course, the tube is subjected to a violent physical shock, which might jar an element loose or break continuity between the wires connected to the tube prongs and the elements. Usage will not alter the plate impedance or the mutual conductance values if the filament emissivity remains constant. With respect to disconnected elements, this condition will be evidenced by certain symptoms and will become evident in a simple plate current test which follows the filament emission test, the latter, however, being the first test made.

We have already said that the most vulnerable part of any vacuum tube, irrespective of type, is the filament. Furthermore, the element which deteriorates most rapidly during operation of the vacuum tube is the filament. In the filament type of A.C. tube, the filament is the source of electrons, exactly as in the case of the D.C. tube. In the cathode type of A.C. tube, the cathode is the source of electrons. Hence, if in the first two instances, the source of electrons undergoes the most rapid change, the same may be considered to be the case in the cathode type of A.C. tube. In addition, we must consider volatilization of the filament in this tube and the production of less heat with which to heat the cathode, and also burn out the filament. Since the operation of the tube is governed by the electronic emission by the electron emitting element, the primary test is that for

electronic emission. In the D.C. type of the tube employing a thoriated filament, the thorium is burned away and the abundant emission of electrons, due to the thorium ceases. Since the tube is designed for operation with the thorium in the filament, deactivation of this type of filament will impair the operation of the tube.

The same is true in the case of filament type of A.C. tube, with the exception, that in this instance, the abundance of electrons is due to an oxide coating upon the filament. After this oxide is burned away, the filament does not emit sufficient electrons for satisfactory operation. In the cathode type of A.C. tube, the cathode is the electron emitter, and if the heat generated by the filament (heater) is insufficient, the electronic emission will be insufficient. If, on the other hand, the oxide coating upon the cathode is burned away during operation, the number of electrons emitted will reach a low level and thus render the tube useless.

Emission Tests—Electronic emission tests must be made under definite prescribed conditions, a requirement which is not fulfilled in everyday practice. These specifications are compiled by the vacuum tube manufacturers. It is true that each individual can develop his own calibrations for electronic emission, but no matter how it is arranged, definite values must be employed. Every type of vacuum tube has a definite minimum value of electronic emission at certain values of filament and plate potential. This, however, does not signify that all tubes are tested under identical conditions, unless they are of similar type, in which case what has been said does not apply, and all tubes of similar type are tested under identical conditions. Electronic emission in excess of the minimum value is permissible.

The following is the minimum electronic emission value of each tube mentioned and the recommended operating voltages.

Tube	Fil. Volts	Plate Volts	Minimum Emission (Milliamperes)
12	1.1	50	6.0
199	3.3	50	5.5
120	3.3	50	13.0
201A	5.0	50	20.0
200A	5.0	50	14.0
240	5.0	50	14.0
112	5.0	50	45.0
112A	(No emission tests)		
171	5.0	50	40.0
210	6.0	100	85.0
250	6.0	250	505.0
226	1.5	50	35.0
227	2.5	50	35.0
280	5.0	80	100.0 (each anode)
281	6.0	150	200.0

(The plate voltage values mentioned is the voltage applied to the grid and plate connected together as an anode.)

The practice of judging a tube by the normal plate current reading alone, gives very little indication of the tube's performance as an audio amplifier. As a matter of fact, while the plate current is a function of the electronic emission (since the condition of the filament influences the plate reading) filament condition is best determined by an electronic emission test. As a guide to performance as an amplifier, the plate current reading alone will not afford conclusive evidence to the negative or the affirmative since other items must be taken into consideration. These are the amplification constant and the mutual conductance. Fortunately, however, as we stated earlier in this text, measurement of these values is unnecessary. The electronic emission test should be

the first observation followed by any simple test to show correct operating conditions and continuity of the elements.

Tube voltage specifications must be strictly observed. This applies to all voltages: filament, grid and plate.

Plate Current Tests—In contrast to the electronic emission value when testing a tube, the plate current value is a barometer of circuit conditions when testing amplifiers with vacuum tubes in the respective sockets. Experience plus the manufacturer's specifications will advise the correct plate current values for various values of plate voltage, as measured with a meter. Correct interpretation of these values expedite isolation of the trouble.

In connection with what is to follow, we wish to make clear that these conditions are not the only ones encountered. Many others will confront the projectionist but if we remove the haze around a number, the remainder will be viewed in much better light.

In view of the fact that amplifier installations are of two types, namely, those employing batteries as sources of potential and those employing power devices, such as eliminators, for sources of potential, it is necessary to consider them separately. Let us take the battery source of potential first. The first condition shall be excessive plate current, as indicated upon a meter or analyzer, when this device is being employed to check an amplifier and locate the defective part. Excessive plate current may be due to several conditions and for purpose of illustration we show two plate current grid voltage curves in Fig. 2. These curves are for different values of plate voltage and are not the curves of any one specific tube, but are used merely to illustrate the point mentioned. The plate current values are designated upon the ordinate line on the extreme left and the positive and negative values of grid voltages are shown upon

the abscissa. These curves are allied with amplifier operation and circuit conditions may be applied to these curves for interpretation. If one comprehends this data, much will be gained.

The designations "Ep 90" and "Ep 135" mean that the first curve is representative of a condition when the plate voltage is 90 and the other when the plate voltage is 135. Let us consider "0 grid volts" as the starting point for our discussion. The plate current values indicated on the ordinate are the values indicated on the set analyzer plate current meter. According to the curves in Fig. 2 the normal plate current for Ep 90 and 0 grid bias is 10 milliamperes and for Ep 135 and 0 grid bias, the normal plate current is 12.5 milliamperes. It is, therefore, obvious that as the plate voltage is increased, everything else being normal the plate current increases. Discounting the plate current saturation point governed by this maximum filament emission, it can be said that excessive plate current may be due to excessive plate potential. If we could draw a curve for Ep equal to 200, the plate current with 0 grid bias would be much greater than 12.5 milliamperes.

Now, suppose that we operate with the curve marked Ep 90 and consider the positive and negative grid bias voltages. According to the graph, the negative voltage has a maximum of 20 volts and the positive voltage a maximum of 8 volts. The reason for the unequality is that positive bias is seldom employed. We neglect the small positive bias employed with grid leak condenser systems of detection, since the bias does not approach the maximum of 8 volts shown. For a plate potential of 90 volts, the usual grid bias is about 4 volts or perhaps a little more. According to the curve, the normal plate current with this plate and grid voltage is about 6.3 milliamperes. We are aware that this value is in excess of the usual value encountered in amplifiers, but

we employ it because it is better for illustration. 0 grid bias the plate current is 10 milliamperes, an increase of approximately 3.7 milliamperes when the 4 volt grid bias is removed. It is, therefore, evident that the grid bias controls the plate current and if the grid bias is less than normal the plate current will be more than normal, hence excessive plate current may be due to insufficient grid bias. If we move into a territory occupied by the positive grid bias voltages, we find that with a grid bias of plus 4 volts the plate current is increased to 12.5 milliamperes, (the curvature of the plate current curve has no significance) and if the normal plate current is supposed to be 6 milliamperes (Ep 90 with 4 volts

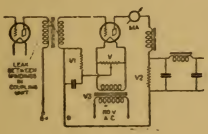


FIG. 6

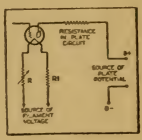


FIG. 7

negative grid bias), it stands to reason that excessive plate current may be due to incorrect polarity of the grid bias—the bias being positive instead of negative.

Referring again to figure 2, it is evident that the grid bias controls the value of plate current, when the plate voltage is normal. Also that if the plate voltage is less than normal it is still possible that the plate current should be excessive as for example—the normal plate current for Ep 135 and 8 volts negative grid bias is 6 milliamperes, the plate current for Ep 90 and 1 volt negative grid bias is 9 milliamperes. Although lacking an illustration, excessive plate current may also be due to excessive filament potential.

With the above in mind and with one exception, it

stands to reason that the reverse conditions may cause insufficient plate potential with normal bias and may be the cause for insufficient plate current. Likewise, excessive negative grid bias may be the cause for insufficient plate current. The exception we mention is the application of a positive grid bias, which can never cause insufficient plate current, since it will always increase rather than decrease the plate current.

Floating and Positive Grid—In connection with this discussion of plate current, we must mention another condition before we move on, and this is an unsteady or fluctuating plate current observation. Contrary to the opinion of many, this condition does not indicate a poor contact in the plate circuit. Instead, it is due to an open in the grid circuit, resulting in a "free" or "floating" grid. The fluctuating plate current is an indication that the grid is not at a steady operating potential; the grid intermittently accumulating a heavy negative charge which reduces the plate current to zero or thereabouts and then losing this charge, again permitting normal plate current, only to again repeat the procedure. The proof that this condition is not due to a poor contact is that the variation is uniform in frequency and is found when the amplifier is not passing signals and that the plate voltage is normal and steady at all times, even when the plate current is zero.

Now, we refer to Figs. 6 and 7 to illustrate the points mentioned in connection with the curves in Fig. 2 and to bring out a few pertinent details which were not represented and discussed in Fig. 2. In Fig. 6, we view an ordinary stage in an electric amplifier, employing an eliminator as the source of grid potential, the potential being due to the passage of the tube plate current through the resistance and the consequent voltage drop. Referring to excessive plate current with normal plate potential we find that a leak between the plate winding of the trans-

former connected to the plate of the preceding tube and the grid winding of the tube in question will cause the application of a positive potential upon the grid, which will either neutralize the negative grid bias or will submerge the negative grid bias, and cause a positive bias. This condition arises frequently in resistance-capacity audio amplifiers and in some impedance-capacity audio amplifiers, due to a leak through the isolating or coupling capacity as many call the condenser. Other cases have been in the radio-frequency transformers where scraping of the insulation permitted contact between the plate and the grid turns, or some other form of short; also a leak between the plate and grid windings of audio frequency transformers or between the plate and grid leads.

General Voltage Checks—Referring to Fig. 6, we have designated four important sources of potential; V, V1, V2, and V3, each one having a bearing upon the reading observed upon the plate current meter, MA. If the plate current is excessive and the measurement of the plate voltage shows it to be greater than normal, V, V1 and V3 are not involved and examination of V2 is in order. The possible troubles in the source of V2 are two in number. First, the input voltage, and second, the voltage drop across the voltage divider resistance, or an open in the voltage divider resistance. The condition of the voltage divider system is evidenced by the plate voltages applied to the other tubes in the amplifier. If voltage is being applied to the detector tube plate, and the voltage divider system is of the potentiometer type, it is safe to assume that nothing is wrong with the divider resistance. Even if the resistance usually employed between the detector tap and the B minus is open, satisfactory operation will be possible, although the output voltage will be higher along the various taps, because the insertion of this resistance increases the current load upon the eliminator.

It is now necessary to consider the operating characteristic of the average B eliminator. If the current load is reduced the output voltage increases and, conversely, if the current load is increased the output voltage decreases. This condition is influenced by the grid bias, the output voltage increasing as the negative bias is increased, since this action reduces the plate current, hence the current load. In this case however, the plate current is excessive, hence, it is doubtful if it is due to excessive grid bias. If the grid bias were positive, it would cause the increased plate current, but such an increase in plate current load would have a tendency to reduce the output plate voltage. But one conclusion is possible—at some other point in the amplifier the load upon the amplifier eliminator has been removed or reduced. Perhaps a plate circuit is open, or if the voltage divider employed in the eliminator utilizes individual resistances, one of these resistances is open.

If the tube under observation is the output tube, it is possible that the lead supplying plate voltage to the other tubes is open, and vice versa. If the voltage divider system is of the potentiometer type and the tube being tested is one of the amplifying tubes, exclusive of the output tube, an open in the voltage divider system between the amplifying tube tap and the main lead is out of the question, since such a break would open the circuit and the plate voltage necessary for the work would not be available for the tube being tested. However an open between the maximum voltage drop and the output tube plate is possible and such a condition would cause the application of excessive potential upon the plate of the tube being tested.

We must also consider another possibility, the lack of function of voltage reducing resistances in the plate circuits, exclusive of the voltage divider resistances in the eliminator. An idea of what we mean is shown in Fig.

7. The tendency towards excessive plate current with excessive plate potential, due to the condition cited, is greater when the C bias resistance is incorporated in the eliminator, rather than in the grid circuit of the tube in question, as shown in Fig. 6. In the latter position the grid bias voltage increases as the plate voltage and plate current increases.

CAUSES OF LOW PLATE VOLTAGE

It is impossible to give a detailed analysis of the reasons for all conditions to be encountered in a defective amplifier. However we shall consider at length, the condition mentioned above and later make mention of the reasons for other conditions, without delving into the ramifications of this subject.

Insufficient plate voltage and plate current may be due to several conditions in the system. First, a marked reduction in the input voltage feeding the B eliminator. Second, excessive voltage drop in the eliminator rectifier tube or element, due to defective condition of the tube or element. Third, excessive voltage drop in the filter system. Fourth, a shorted bypass condenser across one of the sections of the eliminator voltage divider resistance network, which would reduce the total network resistance, increases the current flow through the network, hence the current load. This would cause a reduction in the total output voltage. Furthermore, if the C bias resistance is located in the B eliminator, the action mentioned would cause a marked increase in negative grid bias, consequently increases negative grid bias and greatly reduces tube plate current. In this discussion we assume that the shorted condenser is not connected across one of the plate voltage taps which supplies plate voltage to the tube under test.

With respect to V1 in Fig. 6, we must mention a similar resistance located in the B eliminator. In both cases the resistance is bypassed with a capacity. A short in this condenser will short the resistance and eliminate the C bias, thus greatly increasing the plate current and

reducing the plate voltage, due to the operating characteristic of the B eliminator. However the reduction in plate voltage will not equal the increase in plate current, that is, in effect.

With respect to an open in the grid circuit, two conditions may prevail, depending upon the position of the break. If the "open" is located between the grid of the tube socket and the grid end of the unit connected across the grid filament circuit the "free" grid condition mentioned will prevail. On the other hand, if the break is located at a point where it opens the filament minus B circuits, the plate current meter will read zero, since circuit continuity between the plate and filament has been broken. Such a condition would exist if the grid bias resistance supplying V1, in Fig. 6 were to open.

The value of the resistance associated with the designation V1 in Fig. 6 governs the value of the grid bias applied to this tube. If it is excessive, the negative grid bias is excessive and the reading on the meter MA will show insufficient plate current. Conversely if the value of resistance is less than normal, the reading on the meter MA will be greater than normal, showing excessive plate current.

Insufficient or excessive values of V, the filament potential, is governed by the value V3, the input voltage, when a transformer is used, and the potential value of the battery, if a battery, or an eliminator is used. Also upon whatever voltage reducing resistances may be employed in the filament circuit, as shown in Fig. 7. If, assuming correct source of potential, these resistances are excessive in ohmic value, the value of V will be less than normal and the reading on MA will be less than normal. If, on the other hand, the ohmic value of these resistances is less than normal, the value of V will be greater than normal and the reading on MA will be greater than normal.

As we stated we cannot due to lack of space, delve into the innermost details associated with various conditions. We will however enumerate the possible reasons or causes for various conditions. We of course understand that reference to these details cannot be made during the process of servicing. However comprehension of what is contained in these pages will fortify the service man and projectionist with sufficient knowledge that he may interpret into practice. We hope that the reader realizes that these details pertaining to filament, grid and plate voltages are associated with the commercial or as far as that goes, with all set analyzers. It is unnecessary to mention the application of these testers, i.e., how to employ the testers. We hope to explain interpretation of the meter indications.

Let us therefore devote some time to facts associated with various voltage and current indications, since these figures constitute the basic analysis.

Excessive plate current with normal plate voltage may be due to:

1. Excessive filament voltage.
2. Insufficient grid bias.
3. Defective tube.
4. A leak between the grid and plate windings of the coupling unit.
5. Incorrect polarity of the grid bias voltage.
6. A leaky isolating condenser in a resistance or impedance coupled amplifier.

The foregoing are probable causes for excessive plate current with subnormal plate voltage. It is possible that one of these conditions may cause excessive plate current when the plate voltage is excessive. In this connection it is necessary to add the possibility of excessive plate voltage.

Insufficient plate current for normal and excessive plate potential may be due to:

1. Insufficient filament potential.
2. Excessive grid bias.
3. Excessive voltage drop across unit in plate circuit.
4. Incorrect polarity of grid bias, where correct bias is positive to grid.
5. Open grid circuit.
6. Defective tube.
7. Deactivated filament.

Erratic behaviour was mentioned earlier in the text.

Excessive plate potential may be due to:

1. Insufficient load upon Power B device.
2. Excessive battery voltage.
3. Insufficient voltage drop across units in the circuit.
4. Excessive line voltage feeding power B unit.
5. Excessive grid bias potential when secured from B unit.
6. Insufficient grid bias potential when secured from B unit.
7. Incorrect tap on battery or power B unit.
8. Open in voltage divider system of B unit, between Det. and B minus.
9. Shorted filter chokes.

Excessive filament potential may be due to:

1. Incorrect adjustment of voltage reducing resistance.
2. Excessive battery voltage.
3. Insufficient load upon transformer winding.
4. Excessive line voltage feeding transformer.
5. Incorrect voltage reducing resistances.
6. Incorrect adjustment of power A device.
7. Excessive line voltage feeding A eliminator.
8. Shorted filter choke in A eliminator.

Insufficient filament potential is due to the reverse conditions mentioned for excessive filament potential. Also

1. Incorrect line voltage reducing resistance.
2. Wrong tube in socket and excessive current drain.

Excessive grid bias may be due to:

1. Excessive grid bias battery voltage.
2. Excessive value of resistance when bias is secured from power V unit.
3. Excessive value of grid bias resistance at any point in system.

Insufficient grid bias may be due to the reverse conditions mentioned in connection with excessive grid bias. Also

1. Shorted grid bias resistance bypass condenser.
2. Leaky grid bias resistance bypass condenser.

Insufficient plate potential may be due to:

1. Defective rectifying tube or element.
2. Excessive load upon power B device.
3. Excessive voltage drop in power B filter system.
4. Leak across rectifying system.
5. Insufficient line voltage input.
6. Insufficient voltage input into rectifying system.
7. Excessive current drain across voltage divider network.
8. Shorted section of voltage divider network.
9. Excessive resistance in cable between source of potential and tube.
10. Excessive voltage drop across voltage reducing resistance in plate circuit.
11. Leaky plate circuit bypass condenser.

The testing of a tube used in a sound picture amplifier is quite a problem since regular testing devices are not available. The only guide is the current and voltage specifications furnished by the manufacturer. Hence the only practical method is to compare the plate current consumption of a suspicious tube with the plate current consumption of new tube known to be good. A better system if possible is to place the tube into its regular socket and measure the plate current. Then to alter the grid bias by a few volts. The change in plate current should be noted and compared with the plate current

variation of a new tube. Good tubes will show marked change in plate current when the grid bias is varied. This grid swing test is most effective if it can be applied.

With respect to the comparison of two tubes employed in a push-pull system, one cannot say definitely that the tube which causes the greatest current flow when used individually or the greatest voltage drop is the best tube. It may be gassy. On the other hand it may be the better tube, better insofar as electronic emission is concerned. The deactivated tube will consume very little plate current, hence will not influence the plate voltage to a marked degree.

Photo-Electric Cell—The photo-electric cell must fall within the vacuum tube classification. Whatever has been said about operating potentials in connection with the regular vacuum tube are applicable to the photo-electric cell. Insufficient polarizing potential will cause a marked decrease in signal output and in contrast to the regular vacuum tube, the window of the cell must be absolutely clean. The same is true in the case of the exciting lamp except that the filament current replaces the polarizing potential. Insufficient current will cause insufficient light and reduced volume, perhaps distortion.

SPEAKERS

THE speakers in use today are of three types:

1. Cone (electro-magnetic).
2. Dynamic (moving coil).
3. Exponential (metal diaphragm).

Of the three types mentioned, the second and third are most popular in the sound picture field. The former finds some application, but it is not prevalent.

Troubles in speakers are several in number:

1. Dead.
2. Sound output is weak.
3. Sound output is distorted.
4. Speaker rattles.

In connection with the cone type of speaker lack of response may be due to lack of signal input, but if we assume the speaker to be at fault the following list should cover the troubles:

1. Open cable connecting speaker to amplifier.
2. Burned out coil.

Both of these troubles may be determined by means of a simple continuity test. First test the speaker cord and second the coils with the speaker cord removed. However, it is possible that the speaker cord or the coils within the speaker are shorted. To ascertain this defect, it is necessary to check the cords individually, that is one cord at a time. The meter reading when testing the coil will show the presence of a short circuit, since the usual resistance of these coils is about 1,000 ohms D.C. hence the meter reading will not be a full reading when the coils are perfect.

Many cone speakers are equipped with frequency filters and an open in the filter coil will cause a "dead" speaker.

If the speaker lacks sensitivity and it is definitely established that the signal input into the speaker is normal and that the speaker cord and coils are in good condition, weak sound output is usually due to weak magnets or to a weak magnet if only one is used. The strength of the magnet is influenced by direct current flowing through the windings and if the polarity of this current flow is incorrect and the current flow maintained for quite a period the magnet will be weakened. This condition is infrequent because the average speaker is so arranged and connected to the amplifier that D.C. does not flow through the speaker windings. In other cases the effect of the direct current flow is balanced in the speaker so that it does not influence the magnet.

Distorted sound output may be due to distorted input, but, if the input is known to be satisfactory the possible reasons are:

1. Imperfectly adjusted armature.
2. Damaged cone.
3. Imperfectly centered cone.
4. Defect in filter, if filter is used.
5. Incorrect coupling unit, coupling speaker in tube.

Visual examination is necessary in 1, 2, 3, and 5. An electrical test is necessary to determine 4. The armature must be accurately centered between the pole pieces. A torn, cracked or unevenly stretched diaphragm will afford poor sound output. An imperfectly centered diaphragm will distort on loud signals.

A defect in the filter or the use of incorrect electrical constants will affect the frequency response, as for example a shorted filter choke will cause the loss of high notes if the value of the condenser is high. However, the usual speaker filter is designed to cut off at a pre-

determined frequency, which condition will be upset by a defect in either unit.

In turn the use of the incorrect coupling unit will cause a decided loss in low frequency response.

The rattle in a speaker may be due to:

1. Incorrectly centered armature.
2. Loose moving parts in driving motor.
3. Loose diaphragm.
4. Foreign substances interfering with motion of moving elements.

The remedies are self-evident and in all cases the defect is found by visual examination.

Hum is frequently a complaint. Since nothing is utilized in the speaker, which may cause the hum and if the hum is not in the amplifier output, the fault is induction between a line supplying power to the amplifier or to the lights in the room, and the loud speaker cord. This is particularly true when the cord extends from one room to the next.

In some cases an output coupling unit is incorporated in the speaker housing. In this case it is necessary to add to the possible reasons for a "dead" speaker. Another possible reason is an open plate coupling choke. A second is a shorted plate coupling choke, a third, an open secondary if the output unit is a transformer and the fourth reason, a shorted secondary winding.

5. Loose frame, screws, adjusting nuts, etc.
6. Damaged cone.
7. Loose grill and housing attachments.

With respect to sound units used with old horns and horn type speakers "dead" units may be due to

1. Open cable.
2. Shorted cable.
3. Open coils.
4. Shorted coils.

Lack of sensitivity may be due to

1. Weak magnets.

Distorted sounds and noises during operation may be due to

1. Bent diaphragm.
2. Loose diaphragm.
3. Foreign particles on pole pieces.
4. Excessive signal input.
5. Loose moving parts.
6. Loose nuts, washers, etc.

The dynamic speaker introduces a few complications because the design of the unit involves several additional items. In some cases the apparent speaker defect is due to a defect in an auxiliary unit. Assuming the trouble to be in the speaker and its accessories, when the speaker is "dead" look for

1. No signal from amplifier.
2. Lack of excitation voltage.
3. Open field winding.
4. Open primary of output transformer or open plate choke.
5. Open voice coil.
6. Disconnected voice coil.
7. Shorted field winding.
8. Shorted voice coil.
9. Open fuse circuit.

All of the above with the exception of number 6 calls for continuity testing. In this work it is necessary to consider whether or not the correct condition of a coil means an appreciable amount of D.C. resistance. For example the voice coil in many dynamic speakers consists of a band of 1/16" copper. The D.C. resistance of this coil is less than an ordinary short circuit with No. 22 wire.

Distortion output may be due to distorted input, but if it is established that the input is satisfactory, look for

1. Incorrectly centered voice coil.

2. Defective coupling unit, coupling voice coil to amplifier.
3. Imperfectly centered cone.
4. Damaged cone.
5. Excessive hum.
6. Incorrect coupling between output and voice coil.

The first four items require visual examination. The fifth item requires special consideration since the cause for hum may be poor operation of the eliminator supplying the excitation voltage. We need not dwell upon the eliminator supply since that item is covered at full length in another section. However, very satisfactory eliminators do not afford absolutely pure D.C. output, and several methods are employed to eliminate the hum generated in the speaker.

Lack of sensitivity may be due to:

1. Insufficient excitation voltage and current.
2. Partially shorted field winding.
3. Partially shorted voice coil.
4. Extreme rigidity of diaphragm.

Rattles heard during operation may be due to

1. Incorrectly centered voice coil.
2. Loose moving parts.
3. Loose voice coil.
4. Foreign substances between coil and pole piece.

AMPLIFIERS

Audio amplifiers in use today employ three distinct methods of coupling

1. Transformer.
2. Resistance.
3. Impedance.

with variations of 2 and 3, where combinations of resistance and impedance and resistance and auto transformer coupling are involved. However, no matter what the arrangement the function of the system is always the same. This does not mean that the performance is the same. Our purpose is not to outline the operating characteristics of various types of audio amplifiers. Instead to concern ourselves with troubles in audio amplifiers. We take for granted and we are justified in so doing, that the audio amplifier incorporated into any receiving system is best suited for that system. Furthermore that the design of that audio amplifier is as good as can be made under existing conditions. Operating on this premise we eliminate the subject of amplitude distortion in audio amplifiers, wherein is involved the frequency characteristic of the amplifier in question.

The vacuum tube employed in an audio system plays a very important role, because it manifests a great influence upon the performance of the amplifier and the attainment of satisfactory results. Unfortunately, space limits us to general discussion. Hence the following:

1. High Mu tube or tubes designed to possess high values of amplification constant are suitable for use in two types of audio amplifiers, resistance coupled and im-

pedance coupled and are NOT suited for use in transformer coupled systems.

2. The conventional type of low Mu tube represented by the 226 and 227 is suitable for use in all types of audio amplifiers but is limited for use in all stages except the output stage. This does not mean that a power tube cannot be employed in an intermediate stage in the audio system, but it is mentioned so as to define the limits of the regular tube.

3. D.C. tubes such as the 239A are NOT suited for operation with raw A.C. filament potential, but may be employed in series filament connection when the filament supply is D.C. secured from the A.C. power line or batteries. The same applies to the 112.

4. The screen grid tube utilized as a space charge tube is UNSUITED for use with transformer coupling. This applies to the A.C. and D.C. tubes of this type. This tube is suited for use with resistance and impedance coupling when the resistances and the chokes are specially designed for the tube.

5. The 226 and the 227 are suitable for use in audio amplifier systems operating with raw A.C. filament potential, but greater satisfaction is secured with the latter.

6. All types of tubes may be employed in push-pull arrangement providing that the system is designed for such work.

7. The utility of power tubes such as the 210, 245, and the 250 is governed by the required output power and the amount of voltage available for application to the grid of the output power tube.

8. Output power tubes should be interchanged unless the required operating potentials, grid, filament and plate, are available. The reason for this is that the output power is a function of the operating potentials.

9. It is necessary to remember that the operating characteristics of the output tube differ from the other

tubes in the amplifier. This difference is found in the function of the output tube. Whereas the other tubes in the amplifier perform as voltage amplifiers the output tube is a power amplifier and the power output varies as the square of the input. In other words if a tube is rated at 4 watts output with a certain value of plate potential and 40 volts applied to the grid, the application of 20 volts to the grid reduces the output power to ¼ of the maximum output or 1 watt and NOT to ½ the maximum power or 2 watts.

10. The difference between the output power tubes and the other tubes in the audio amplifier is one of physical structure which permits the application of higher values of plate potential and grid bias so as to enable the application of high signal voltages to the grid of the power tube without causing overloading and distortion. Furthermore, the design of the power tube is such that it affords best energy transfer between the tube and the speaker over the normal audio frequency range, therefore affording best tone quality.

11. All tubes are suited for series or parallel filament connection, although it is not customary to employ the A.C. tubes in series connection.

12. The design of all vacuum tubes is such that operating voltage specifications must be fulfilled and adhered to. Excessive operating potentials may cause irreparable injury to the tube. This is particularly true of the filament.

13. Insufficient filament, plate or grid potentials will impair the operation of all vacuum tubes. The advent of the screen grid tube makes necessary mention of the screen grid voltage in addition to the other voltages quoted.

14. Amplification in a system should not be secured by increasing the operating potentials unless the value

in use before the change is made is less than the maximum.

15. Volume control should not be in the form of reduction of operating potentials, such as the filament or plate voltages. Reducing the grid voltage is out of the question. (The above applies particularly to the audio amplifier, since plate voltage volume control is used in radio frequency amplifiers.)

16. Vacuum tubes of all types have definite operating lives, determined by the operating potentials applied to the tube. The most valuable part of the tube is the filament and operating life is limited by the deactivation of the filament or decreased in electronic emission. The 227 type of tube involves the cathode as the source of electrons.

17. Operating characteristics of vacuum tubes are such that certain conditions must be fulfilled in order that the amplification be free from distortion. The first is the elimination of grid current. D.C. current must not be permitted in the grid-filament circuit since it introduces distortion and reduces amplification by varying the characteristic of the tube and the coupling device. This applies equally to all forms of audio amplification. The second is that circuit arrangement must be such that the plate current variations in the plate circuit should be faithfully amplified reproductions of the signal voltage applied to the grid circuit. This means that every increase and decrease in signal voltage should be faithfully followed by plate current variations in the plate circuit. Since these plate current variations are A.C. the D.C. plate current must be steady, hence fluctuations of D.C. plate currents should not be permitted during operation. They indicate lack of balance between the plate and grid voltages. Increase in plate current during passage of the signal indicates tube overloading, distortion or insufficient grid bias.

18. Where more than one tube is employed in a single stage, as in a parallel or a push-pull stage, it is best if the tubes are of like design and characteristics. This condition affords more stable operation. With respect to the plate current drain in push-pull stages, best results are secured if the total current drain is divided equally between the various tubes in the stage. This division of plate current is also advantageous with respect to the effect of the direct current upon the core of the coupling unit (if it employs a core) in the plate circuit.

19. Vacuum tubes may be connected into parallel and push-pull arrangements when additional output is required. However, the power output of two tubes in parallel is not equal to twice the output of a single tube. Empirical determinations have shown an increase of about 30 to 40%. Furthermore, the use of tubes in parallel does not permit a signal voltage in excess of that permissible with one tube.

20. Push-pull arrangements afford advantages not found in parallel systems. In the first place, it is permissible to apply a greater value of signal voltage, approximately twice that permissible with one tube. Second the output is greater than that available with two tubes in parallel. Third, the operating characteristic of the tube is altered so that greater freedom from distortion is secured. Fourth, push-pull systems minimize hum due to potential variations in the grid-filament circuit due to the hum in the filament supply or induced into the grid circuit.

21. The association between the vacuum tube and the device connected into the tube plate circuit is very important, so much so that it is the difference between good quality reproduction and poor reproduction. Hence haphazard replacement of defective coupling units is impossible. When one unit is removed, the replacement should be identical.

22. With respect to the plate voltage applied to vacuum tubes, it is necessary to remember that a voltage drop takes place across the coupling unit located in the plate circuit. This means that the voltage at the tube plate is less than the voltage at the source of supply. Due to the current carrying capacity of the coupling units, plate voltage increase is definitely limited, since each increase in plate voltage increases the plate current and flow through the coupling unit. Excessive current flow will injure the plate coupling unit, regardless of its type.

23. Do not remove tubes from series filament installations unless the proper precautions are exercised to prevent overloading of the other tube filaments. The same is true of tubes in parallel connected across transformer windings.

FORMS OF COUPLING—The choice of any one type of coupling unit is a matter of like and dislike. Also of the required frequency characteristic. In this connection we can say very little since the amplifier designer is the one who decides upon the type of coupling employed in the amplifier.

With respect to trouble, however, all amplifiers are alike. Not that the same trouble will be found in all types of amplifiers since different types of coupling units are afflicted with different forms of trouble, but rather that the basic factors associated with trouble are present in all amplifiers.

To secure satisfactory operation with all amplifiers, certain requirements must be fulfilled. A defective condition means that one of the requirements has not been fulfilled. The conditions are:

1. Input signal voltage within operating limits of vacuum tubes in the system
2. That the plate potential at the tube plate be correct
3. That the grid potential at the tube grid be correct

4. That the filament potential at the tube filament be correct
5. That the coupling units be in perfect condition
6. That circuit wiring be correct
7. That connections in the circuit be perfect
8. That all the amplifier components be in good condition
9. That the filament supply be in good condition
10. That the grid supply be in good condition
11. That the plate voltage supply be in good condition
12. That the tubes be the type suited for the receiver
13. That the tubes be in good condition.

A cursory analysis of the above is sufficient to show that each of the subjects is allied with the other and also associated with certain phenomena. To expedite matters, we believe that it is better to give basic reasons for the various requirements, thereby permitting application of the data to the various types of amplifier and avoiding repetition in the book. We say without fear of contradiction that with respect to trouble all amplifiers are alike. That is to say, the conditions of overload are applicable to all types; the effect of an open is the same in all amplifiers; the effect of a short circuit is the same in all amplifiers, etc. Hence why dwell upon the individual types.

Bear in mind that what is to follow is applicable to all types of audio amplifiers regardless of circuit connection and the number of tubes involved, assuming that the amplifier has at least one tube. . . . The numerical designations refer to the requirements as enumerated.

1. The value of grid bias employed in the amplifier system limits the amount of signal voltage which may be applied to the tubes in the receiver. This is true of all types of installation, since the type of coupling does not influence the operating potentials. In other words if a 112 requires a negative grid bias of 6 volts with

135 volts applied to the plate, the same grid bias is required in transformer, resistance and impedance coupled audio amplifiers. The application of excessive signal voltage will cause tube overloading, grid current and distortion. In this connection it is necessary to consider the degree of amplification available in the system, so that overloading of the output tube does not take place. Incidentally, the most frequent complaint relative to tube overloading is that in connection with the output tube. The data relative to the action of the plate current is of utility when tube overloading is the subject.

2. Incorrect plate potential causes several bad effects and may be due to several conditions. With respect to the value of potential, insufficient voltage applied to the plate will cause low amplifying level, permit overloading of the tube and consequently distortion. On the other hand, excessive plate potential will upset the balance between the grid and plate circuits, it will increase the plate current and if the increase is radical, permanent injury of the coupling unit is possible. If the injury is of such nature that it does not ruin the unit, it is possible that the damage will cause noisy operation. This is true in the case of resistances and transformer winding. In addition, it is necessary to accord detailed thought to the magnitude of plate current when the coupling unit is a transformer employing an alloy core. The design of the core is such that the permissible D.C. plate current through the transformer winding is limited. Excessive current will ruin the core electrically and impair the frequency characteristic of the transformer. The usual effect is the loss of low notes.

3. Low grid potential is a frequent cause of distortion. The operating principles of the vacuum tube demand that a certain value of grid potential be employed for each value of plate and filament potential in order to

create a state of stability between the grid and plate circuits. The attainment of distortionless amplification with the vacuum tube depends upon the elimination of grid current in the tube grid-filament circuit. This is true of all types of amplifiers without exception, transformer, resistance and impedance coupled parallel tube filament wiring and series filament wiring. The elimination of grid current depends upon the use of the correct value of grid potential. The subject of correct grid potential, involves excessive potential, insufficent potential, lack of grid potential and incorrect polarity, consequently the source of grid potential, circuit connections and associated apparatus. The possible reasons for incorrect grid potential have been outlined in another section, hence repetition is unnecessary, but it is necessary to mention that the grid bias controls amplification.

Insufficent grid bias of correct polarity will cause tube overloading on strong signals only, but the condition will be shown by excessive tube plate current. Incorrect polarity of grid bias will cause extremely poor amplifier operation and a great reduction in amplification. As a matter of fact it will paralyze the tube and the amplifier will be inoperative. The sign of this condition is a great increase in tube plate current in excess of the normal value. Excessive grid potential will cause distortion and if the bias is sufficient to reduce the plate current to zero the amplifier tube will be inoperative and the amplifier will be inoperative. This condition is indicated by insufficient plate current.

4. The value of filament potential governs the operation of the tube, the performance of the tube, and its operating characteristics. In addition it manifests an influence upon the operating life of the tube with respect to the operating life of the filament. Excessive filament potential will cause premature deactivation of the filament and eventual burnout. Insufficient filament

potential on the other hand will cause low amplification and distortion, such as tube overloading. In addition the mutual conductance value of the tube is greatly reduced and the plate impedance value greatly increased, impairing the operating characteristic of the tube with respect to the units employed in conjunction with the tube. Increased filament potential will not cause a marked effect upon the plate current, but insufficient filament potential will cause a marked decrease in plate current.

5. The condition of the coupling units in the system, regardless of type controls the amplifier performance. If for some reason the grid or plate coupling units are "open" operating potentials will not reach the tube and the amplifier will be inoperative. If the plate voltage is lacking the amplifier will appear "dead." If the grid voltage is lacking because the grid coupling unit is "open," various forms of trouble are possible. These are hum, low amplification, distortion and howling. If the coupling unit is defective insofar as the individual plate and grid unit is concerned various defects will be evident, according to the type of defect. If the current flow through a transformer winding causes minute arcing between turns, crackling and frying sounds will be heard. If the core of the transformer is grounded and one of the windings comes in contact with the grounded core, hum and low amplification will be the result. In some cause possible short circuit of the operating potential may be the result. If by chance the primary and secondary windings are in electrical contact with each other distortion will be the result due to the application of a positive bias to the grid. As a matter of fact the aforementioned condition may cause total paralysis of the tube and an inoperative amplifier.

Imperfect contacts at the respective connecting terminals will cause crackling and sputtering sounds. The

same is true with impedance and resistance coupling. With respect to the latter, overload of the resistance unit will cause hissing and frying sounds. Overload is usually encountered in the plate circuit and is due to excessive current flow through the resistance and the inability on the part of the resistor element to carry the plate current.

The isolating condenser employed in resistance, impedance and in combination resistance-impedance coupled audio amplifiers, between the grid and plate terminals of these coupling units is a frequent cause of distortion, noise and low amplification. A leak in this condenser will cause noise and the application of a positive bias to the grid of the amplifying tube, resulting in low or no amplification in the system; frequently a dead amplifier. The above is true in the audio amplifier employing an auto transformer in the grid circuit and a resistance in the plate circuit of the preceding tube with the isolating condenser between the two. This system will be shown later.

Certain transformer coupled audio amplifiers employ an isolating condenser in the plate circuit in conjunction with the regular transformer primary and another choke. The function of the condenser is to exclude D.C. from the transformer primary. A leak in this condenser will cause noise during the passage of signals and a short in the condenser may reduce amplification on the low frequencies. A good deal of the noise encountered in audio amplifiers is due to some imperfect condition in the coupling units and examination by replacement is recommended. This is particularly true of transformers operating at high potentials and resistances employed in high power audio amplifiers or resistances which are subjected to appreciable values of current load.

6. Much trouble in amplifiers may be attributed to poor connections between the various elements. The

average amplifier is subjected to many jars and shocks during transit or installation. A poorly soldered contact is jarred loose. It makes contact until vibration encountered during operation opens the contact—then trouble. In many other instances the contact is not permanently opened. Instead it breaks and makes intermittently during operation. The result is electrical disturbance in the form of sputtering and crackling sounds and sometimes distortion and low amplification, depending upon the location of the poor contact.

7. We discriminate between the coupling units in the amplifier and the other parts exclusive of the tubes. We refer to the resistances employed in filter systems, the condensers employed in the filter system, the bypass condensers, the voltage reducing resistances, the tube sockets, etc. In order to secure satisfactory operation, it is necessary that all these parts be in perfect condition. Shorted bypass condensers will short associated circuits, cause low amplification, short battery life, overloading of power supply devices, lack of plate potential, lack of grid potential, etc., depending upon the location of the bypass condenser. These details are of interest after the trouble has been isolated with respect to a certain stage in the amplifier or a certain section of the amplifier.

Defects in voltage reducing resistances will open the respective circuits. Defects in filter resistances carrying the tube plate current will either open the circuit, cause excessive voltage drop or will cause noise of the character mentioned in preceding sections of this chapter. Defective sockets will cause leaks between the various circuits and distortion, low amplification and sometimes stop operation of the amplifier. The latter condition involves the contact between the tube prongs and the socket contacts. Poor connection between the tube and the sockets contacts is a frequent reason for fluctuating

signal strength, hum, crackling and sputtering sounds and other forms of disturbance.

Imperfections in bypass condensers, with respect to an open between the connecting terminals and the active surfaces in the condenser will influence amplifier stability, increase regeneration, cause hum and sometimes howling. This is particularly true in A.C. installation.

8. The condition of the filament supply in A.C. installations plays an important role with respect to the hum in the system.

With respect to battery types of filament potential sources, the condition of the battery controls the filament potential. A defective battery will cause low filament potential and in many cases sputtering and crackling forms of electrical disturbance. Corroded terminals will cause noise.

Transformer sources of filament potential are of interest in A.C. installations. An open transformer primary or secondary winding will cause lack of filament potential. Poor contact in the transformer will cause fluctuating filament brilliancy and fluctuating signal intensity. Incorrectly adjusted filament shunt resistance center taps will cause excessive hum. Open filament shunt resistances will cause excessive hum. For further data we refer to the section devoted to filament shunt resistances.

In some cases the source of filament potential is the B eliminator; the amplifier filaments being wired in series and supplied with operating potential from the B eliminator. A defect in the B unit may cause excessive hum and distortion because of incorrect bias and lack of filament potential.

9. The source of grid potential must be perfect. If of the battery type, the electrical condition of the battery must be perfect. A defective battery will cause sputtering, crackling and other forms of disturbance. A run

down battery will cause excessive regeneration, howling, squealing, hum, etc. With respect to eliminator sources of grid potential, defective operation of the eliminator will cause a bad hum and excessive regeneration. Lack of bypass condensers will cause a bad hum and howling. Imperfections in the grid bias resistances will cause hissing and crackling sounds.

10. What has been said about the source of grid potential is applicable to the source of plate potential. Run down B batteries will cause howling and singing in addition to crackling sounds, accompanied of course, by reduced amplification. Defective B supply units will cause hum, excessive regeneration, howling and other disturbing effects.

TROUBLES IN TRANSFORMER COUPLED AUDIO AMPLIFIERS—

DISTORTION—

A. Normal signal intensity.

1. Tube overloading—Signal voltage excessive for tubes in systems. Output voltage from pickup excessive for tubes in audio amplifier.
2. Insufficient grid bias—Grid bias correctly applied but value of potential insufficient for applied signal voltage.
3. Excessive hum in system—Excessive hum in system will cause distortion on low notes.
4. Excessive regeneration—See reasons for excessive regeneration.
5. Defect in speaker—Speaker elements out of alignment or diaphragm loose.
6. Excessive B battery voltage—Incorrect voltage tap on B battery of eliminator.

B. Low signal level.

1. Insufficient filament voltage—Run down A battery, incorrect adjustment of filament control resistance, insufficient line voltage in A.C. systems,

overloaded filament transformer winding, poor contact between tube and socket.

2. Insufficient B voltage—Run down B battery, low B eliminator output voltage, low A.C. input into eliminator, wrong tap on battery or eliminator.
3. Incorrect grid bias—Lack of grid bias, low grid bias, grid bias resistance defective or shorted, incorrect polarity of grid bias.
4. Open grid circuit—Defective grid circuit—Transformer secondary open, open grid bias circuit, open in one half of push-pull winding (secondary), partially shorted secondary winding, wrong connections to transformer secondary, grounded secondary winding, leak between primary and secondary windings, defective resistance or condenser connected across secondary winding, defective bypass condenser in grid circuit.
5. Defective tube—Deactivated filament or cathode, poor contact between tube and socket filament prongs, gassy tube, incorrect tube.
6. Defective units—Shorted bypass condensers in plate and grid circuits, defective jacks, transformer primary partially shorted (push-pull), leak between primary and secondary of output transformer, grounded secondary of output transformer, non uniform tubes in push-pull and parallel arrangement, open transformer primary in parallel plate supply.

AMPLIFYING POWER WEAK—

See data associated with low signal level and distortion. In addition

1. Lack of plate potential—Defective plate circuit—Open between tube and socket, open in transformer primary, shorted transformer primary, shorted plate circuit bypass condenser, open resistance or choke in shunt plate supply, open

coupling condenser in shunt plate supply, open transformer primary in shunt plate supply system, open in lead supplying plate voltage to tube.

HUM—

1. Filament circuit—Incorrect adjustment of the filament shunt resistances, incorrect filament transformer center tap, open filament shunt resistance, coupling between filament transformer or filament wiring and remainder of receiver.
2. Grid circuit—Open grid bias resistance bypass condenser, lack of grid resistance bypass condenser, open grid circuit filter bypass condenser, lack of grid circuit filter bypass condenser, open bypass condenser insufficient grid bias voltage, open secondary winding, grounded secondary winding, grid bias resistance bypass condenser capacity rating too low, pickup of external hum by units in secondary circuit.
3. Plate circuit—Insufficient plate voltage, excessive plate voltage, excessive hum in B eliminator output voltage, open primary input winding, pickup of external hum by units in plate circuit.
4. Lack of ground on core and chassis—Transformer cores and cases are frequently grounded in A.C. installations. Also condenser cases.
5. Reversed power supply plug in A.C. systems.
6. Coupling between amplifier system and detector tube system.
7. Coupling between A.C. line and speaker system cable.
8. Bad hum in detector output voltage. Defective audio tubes.

HOWLING AND EXCESSIVE REGENERATION—

1. Coupling between stages—Transformers too close to each other, grid and plate leads of tubes too

close to each other, speaker cable too close to coupling units in audio system, coupling between speaker cable and amplifier.

2. Microphonic tubes—Operation of speaker causes vibration of tubes loose in sockets, operation of speaker causes vibration of entire cabinet and tubes, moving air volume from operating speaker causes vibration of tube, tube elements loose.
3. Open circuits—Open input winding (primary of input transformer), open grid bias resistance bypass condensers, open plate circuit bypass condenser, lack of bypass condenser, open grid bias resistance, lack of grid bias.
4. Defective sources of potential—Run down A battery, run down B battery, run down C battery, open bypass condenser in B eliminator (voltage divider network and C bias resistance), defective design in B filter system, open in ground system.

NOISE—

1. Filament circuits—Imperfect contacts, poor contact between elements of filament control resistances, poor contact between tube and socket, defective A battery, corroded terminals, gassy A battery.
2. Plate circuit—Poor contact between tube and socket, defective transformer primary, excessive current flow through plate voltage control resistance, defective volume control in plate circuit, leaky bypass condenser, poor soldered connections, loose terminal, defective resistance in B eliminator, defective B battery, defective rectifier in B eliminator.
3. Grid circuit—Poor contact between tube and socket, defective volume control, defective resistance across transformer secondary, defective

transformer, leaky grid resistance bypass condenser, defective grid resistance, loose terminals and connections, poor points, defective resistance (grid bias) in B eliminator, defective rectifier in B supply, defective filament shunt resistance.

TUBES DO NOT LIGHT—

1. Defective tubes.
2. Filament transformers—Line supply circuit open, transformer primary open, tap contacts open, transformer secondary open, poor contacts.
3. Batteries—Run down A battery, corroded terminals, poor contacts.
4. Filament circuit—Defective voltage control resistance, open in wiring, poor contact between tube and socket.

TUBES LIGHT BUT DO NOT SIGNAL—

1. Lack of plate potential—Open in plate circuit, defective B eliminator, open in cable supplying B potential, poor contact between tube and socket, shorted plate circuit bypass condenser, open fuse.
2. Batteries—Incorrect polarity of A battery, incorrect polarity of B battery, incorrect polarity of C battery.
3. Tubes—Defective tubes, deactivated filaments, poor contact between tube and socket.
4. Coupling units—Open primary winding, shorted primary winding, shorted secondary winding, grounded secondary winding, shorted output choke or primary of output transformer, open secondary winding.

RESISTANCE AND IMPEDANCE AMPLIFIERS—The fact that an amplifier employs resistance or impedances or combination of both as the coupling mediums instead of the primary and secondary windings of a transformer does not divorce the system from the

general discussion of transformer coupled audio amplifiers.

Since the design of systems is not of interest to us, we need but mention that as far as trouble is concerned, the defects mentioned in connection with transformer coupled systems are applicable to the resistance coupled amplifier and to the various modifications of resistance coupled audio amplifiers. However, it is necessary to supplement this data with additional information. It is obvious that transformer windings are not involved in a resistance coupled amplifier of the type shown, but burnout of the resistances is the equivalent. Where a choke is employed in place of the plate coupling resistance or in place of the grid leak, it is impossible to apply the quoted data.

Generally speaking, resistance and combination resistance-impedance audio amplifiers are very stable in operation, but certain forms of defects are, however, encountered. Therefore we supplement the audio amplifier data associated with transformer coupled systems with the following:

DISTORTION—

1. Open grid leak or grid choke.
2. Excessive value for the grid leak resistance.
3. Leaky isolating condenser.

LOW AMPLIFYING POWER—

1. Excessive value for plate resistance—A very high plate resistance or a defective resistance will cause excessive voltage drop and low plate voltage at the plate.
2. Low value for grid leak—A shorted, defective or low ohmic value grid leak will reduce the amplification available with the system.
3. Leaky isolating condenser.

MOTORBOATING—

1. Leaky isolating condenser.
2. Incorrect C bias.

3. Lack of C bias resistance bypass condenser.
4. Excessive B potential.
5. Regeneration in system—Defective B supply unit, lack of correct bypass condensers, coupling between grid and plate circuits.

AMPLIFIER TROUBLES

A POWER amplifier consists of two main divisions; first, the power supply which furnishes high voltage plate current, also low voltage filament current; and second, the audio frequency amplifier which steps up the incoming signal voltage to a point where it will operate the power tube.

In turn, each of the two main divisions may be further subdivided, and it is by looking at a power amplifier as being made up of many simple parts that all problems are greatly simplified.

The power supply consists of portions furnishing the high voltages for the amplifier tube plate circuits and of portions furnishing the filament current to amplifier tubes. The high voltage supply includes: first, a transformer for increasing the voltage received from the house lighting circuit; second, a rectifier which changes the alternating current into a pulsating direct current; third, a filter system which smooths out the variations or ripples in the direct current; and fourth, a voltage divider which divides the output between the various plate circuits and, in some cases, between the grid biasing circuits. These divisions are indicated in Fig. 8 for a typical circuit greatly simplified.

The rectifier usually consists of some form of tube. The filter consists of iron-core choke coils in series with one side of the output and of condensers in parallel with the output circuit. The voltage divider consists of resistors which decrease the voltage in the required steps and of bypass condensers between the several voltage taps and the negative or grounded side of the circuit.

The low voltage filament currents for both amplifying and rectifying tubes are furnished either by additional windings on the power transformer secondary side or by separate small filament supply transformers. This completes the power supply portion of the complete power amplifier.

The audio frequency amplifier differs in no particular from a similar amplifier built as an entirely separate unit. This amplifier includes one or more coupling transformers, one or more power amplifying tubes, and

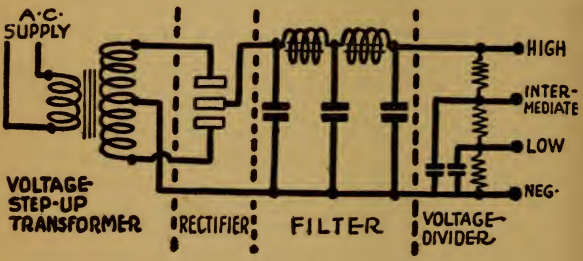


Fig. 8

sometimes one or more voltage amplifying tubes, also the transformer or choke-condenser arrangement through which connection is made to the loud speaker.

Were the audio amplifier built as a separate unit, suitable connections would run between it and the power supply. These would carry the filament, plate and grid bias circuits and the necessary terminals would appear on each part. With the combined power amplifier these connections are made between the parts within the complete unit.

In the study of power amplifiers and in the process of service work upon them, the division of parts should be

kept in mind. Certain actions and accompanying troubles are due to one part and some to other parts. An understanding of the functions of each part is the first step toward giving satisfactory service and toward constructing first class apparatus.

1. Practically all troubles arising in power amplifiers can be placed in two divisions, hum and incorrect voltage. In some instances, these difficulties are so closely interrelated that separation cannot be clearly made. There is nothing peculiar in the electrical action in power amplifiers that differs greatly from similar actions in the radio frequency portion of the receiver. The same fundamentals of inductance, capacity, and resistance apply. However, as is true in every division of the art of sound pictures, the practical use of these properties requires study and application.

2. In locating difficulties in power amplifiers, a high resistance voltmeter should be available. It should have scale readings of 0-50-250-500 volts or something close to these figures. There are times when a scale reading of 0-750 volts is a decided help. Its resistance must be sufficiently high so that there will be no appreciable voltage drop caused by the current necessary to actuate the meter.

A satisfactory voltmeter should have a total resistance equal to at least 600 ohms per volt for the highest scale reading. For example, a meter capable of reading up to 250 volts should have a total resistance of 150,000 ohms or more.

A meter originally designed to measure up to 250 volts may be used with suitable "multipliers" to read up to 500 volts and up to 750 volts. The connections are shown in Fig. 9. Using a multiplier in which the resistance is exactly equal to the meter's total resistance will exactly double the range of the meter, so that a 250-volt type will measure up to 500 volts. Using a

multiplier having double the meter's total resistance will allow the meter to read voltages three times as great as its original scale. Using such multipliers requires that the indicated scale reading on the meter be multiplied by two or by three, depending on the multiplier in use. Manufacturers of voltmeters make suitable multipliers. These are rather costly and for approximate results it is possible to use any fixed resistor of the correct value as a makeshift. Such resistors always vary more or less from their rated values and the meter

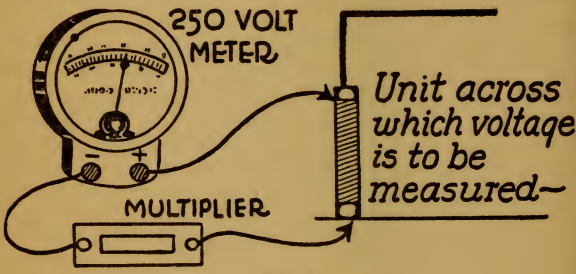


FIG. 9

readings will have a corresponding error. However, the results are near enough to the correct value for most service work.

3. It is also of great help to have milliammeters to read the plate current in the various circuits. Individual meters are more desirable, but multiscale meters can be used by inserting the meter in the circuits in succession. In either event scales of 0-10, 0-50, 0-200 are necessary to afford all possible current drains likely to be met in service work on power amplifiers.

If only a single meter is available, a range of zero to 50 milliamperes is most useful.

4. Another valuable adjunct, although not vital, is an alternating current voltmeter with a multiple scale reading of 3.0, 8.0, and 150.0 volts, maximum. The low scale will handle A.C. amplifier tubes; the intermediate scale will handle all five-volt as well as seven and one-half volt power tubes; while the high scale will measure line voltages.

5. While it is true that access to these instruments is not imperative, the absence of them may result in the destruction of valuable apparatus. Power amplifiers of necessity are expensive and permanent injury to almost any one of the component parts would probably go a long way toward paying for at least the high resistance direct current voltmeter. This is especially true if the constructor has in mind the building of several amplifiers.

6. It is of extreme importance that care be exercised in layout and wiring. It should be realized that a great deal of effort has been spent to make the data sufficiently comprehensive so that if it is carefully followed it will result in an amplifier functioning properly.

7. Regardless of the appreciation of these factors, it is not at all uncommon for mistakes to creep in. It may be that the circuit is not correctly followed, it may be that the builder desires to try out some of his own ideas, it may be that parts have been substituted, or there may be defective apparatus.

8. The most probable source of trouble is in the resistance units. If they are of improper values or defective, the amplifier may not function at all. These units should be carefully inspected to be certain that they are of proper value and checked for open circuits before being placed in the assembly. After they are placed in the circuit, care should be exercised to prevent them being damaged in any way.

9. The next items that should have consideration are

the condensers. Grave damage may easily be caused by using condensers which are broken down or short circuited. Before the condenser is connected into the amplifier, it should be tested for open or short circuits. A simple but effective method of doing this is shown in Fig. 10. This requires a 45-volt B-battery, one side of which should be connected to the common terminal of the condenser and the other side to each of the capacities in turn. Upon making contact with the battery, there is usually a small spark. The contact should be main-

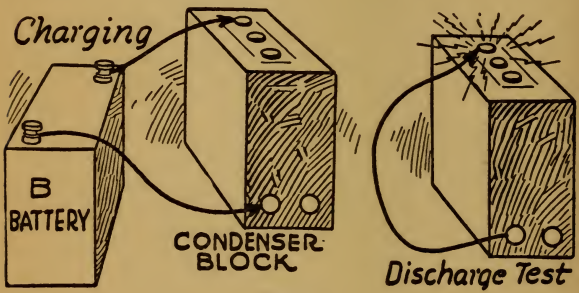


FIG. 10

tained for a short time to insure full charge going into the condenser. After breaking the battery connections and waiting a moment, the lead from the section being tested should be touched to the common terminal of the condenser. When this is done if there is a definite discharge, indicated by a snapping spark, it is quite safe to say that the condenser section is not defective. It is important that careful inspection of the markings of the condenser be made so that the proper capacities will be used in their respective locations.

10. When flexible insulated wire is used to connect

the amplifier it often happens that the insulation is insufficient to withstand the high voltages used, especially if the covering is cracked. It is a wise precaution to use wire having insulation which will stand quite a bit of abuse without being damaged. The high voltage connections may be given added protection by slipping over them a length of spaghetti tubing.

11. It is a good plan to test all transformer windings with a battery and voltmeter as shown in Fig. 11.

In power transformers, the two ends of the high voltage windings are marked "H" and the center tap is marked "C." The two ends of low voltage filament windings are marked "F" and the center tap, when furnished, is marked "C." The winding in any case should be continuous between the two "H" terminals or between the two "F" terminals. It should also be possible to complete a circuit between the "C" terminal and either end of the winding of which this terminal forms a center tap.

In double chokes, one unit is connected between terminal "1" and terminal "C," while the second unit is connected between terminal "C" and terminal "2." The test circuit should be complete between any two of these three terminals. The connections for testing with a voltmeter and dry cell are shown in Fig. 11 for locating open circuits. If the meter shows zero reading, the winding is open between the points being touched.

Each winding may be tested for accidental grounds by using the voltmeter and dry cell combination of Fig. 11 or by using a B-battery and voltmeter similarly arranged. With one test lead touched to the metal case of a transformer or choke and the other touched to the terminals, one after another, the meter should read zero in each test. A voltage reading indicates that the winding connected to the terminal being touched is grounded to the case.

To test for short circuits between windings, the voltmeter and dry cell leads may be connected to the two windings to be thus tested, one lead on a terminal of one winding and the other lead on a terminal of any other winding. There should be zero reading on the meter. Any voltage reading indicates a short circuit between the two windings of which the terminals are being touched at the time.

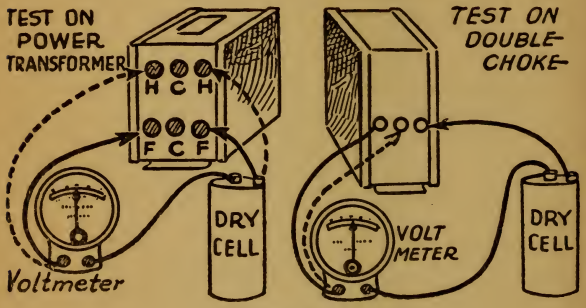


FIG. 11

12. After the amplifier is assembled and wired, it should be carefully checked to make certain that all instructions have been followed exactly and that the wiring is correct. The rectifier tubes should then be placed in their sockets. It is a good plan not to insert the other tubes until the performance of the rectifier tube is observed. With the 110 volt, 60 cycle supply connected, the rectifier tube filaments should light rather dully and there should be no blue haze apparent. If the high resistance direct current voltmeter is available the voltage across the entire voltage divider should be read. This reading will be somewhat higher than actual oper-

ating voltage because there is only the drain of the voltage divider upon the rectifier tubes and this amount of current is insufficient to reduce the output of the rectifiers more than a small amount.

13. If the filaments of the rectifier tubes do not light, wiring of the filaments should be carefully checked. The connections to the sockets and the springs of the sockets should be examined to make certain that the proper terminals of the tubes are being used as the filament terminals and that the terminals of the tubes are making contact with the socket springs. If nothing is apparently defective with these portions of the circuit, either the filament winding of the transformer is open or the rectifier tube filaments are defective. The filament winding may be checked by momentarily short-circuiting the windings and noting whether or not there is a decided spark.

14. If little or no voltage is found to exist across the voltage divider and the rectifier tubes do not become blue or develop hot plates, there is an open somewhere in the high voltage rectifier circuit or the emission of the tubes is defective.

15. To locate trouble of this nature, the high voltage winding should be tested for continuity. It is to be noted that the method of determining whether or not the filament windings are defective, that is, by short circuiting them, must not be applied to the high voltage winding because across this winding a dangerously high voltage exists and permanent injury not only to transformer but also to the individual may result from such methods. Since the direct current resistance of windings of this nature is comparatively high, the voltmeter and battery method of test shown in Fig. 11 will show open circuits or short circuits or grounds. The alternating current must be disconnected, of course, while any tests of this nature are being made.

16. If the high voltage winding is found to be correct, the wiring to the tube terminals, the lead from the center tap of the filament winding to the choke, and the lead from the choke to the voltage divider should be examined. The choke coil should be tested with battery and voltmeter to be certain that it is not open. Any short circuit would probably be shown by the voltmeter reading. The voltmeter requires some current for its operation. The amount of this current flowing through the coil winding will cause a small voltage drop which will depress the voltmeter reading below that obtained when there is no resistance in the circuit, that is, when the voltmeter is put directly across the battery. If all of these things are found to be satisfactory then the emission of the tube is responsible.

17. If the rectifier tubes develop a distinct blue haze or if their plates become red, the tube may possibly be defective, but far more likely, there is some portion of the apparatus that is drawing too much current. In this event, the condensers should be rechecked to make certain they are not broken down. The choke should be examined to determine if it is shorted to the case. The same test should be applied to the power supply transformer. The audio frequency transformers should be tested for connections between the plate or plus B terminals and the cases. Again, the wiring should be very carefully inspected to determine if any accidental short circuits exist.

18. If no unusual behavior is noticed in the rectifier tubes, or if the voltmeter shows approximately the correct voltage across the voltage divider, the amplifier should be disconnected from the alternating current supply and the amplifying tubes placed in their respective positions. The amplifier should now be connected to the 110 volt source and the amplifier tubes closely watched for any abnormal effects, or, if meters are

being used, the voltages and currents carefully noted.

19. If the amplifier tube filaments fail to light, they should be checked exactly the same as the filaments for the rectifier tubes under similar conditions. If the plates become red or if a blue glow is noted, the 110-volt power should immediately be disconnected until the circuits are carefully checked. If meters are available they should be inserted in the following positions and read.

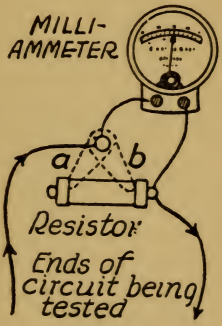


FIG. 12

20. The total rectified current should be read by placing a milliammeter in the lead from the center tap of the high voltage of the power supply transformer. That is, disconnect the lead from the center tap of the high voltage winding, and connect this wire to the plus terminal of the milliammeter, and connect the minus terminal of the meter to the center tap of the high voltage supply. The proper milliammeter must be chosen for this purpose for if the scale reading is too low the meter is liable to be damaged *badly*. A milliammeter should be placed similarly between the plate (P)

terminals on the audio frequency transformers and the respective socket plate terminals. The milliammeter used must be able to carry all the current flowing in the circuit to be tested and, until the meter is connected, it is not always possible to know the amount of this current. An overload, such as caused by an accidental short circuit or ground, might pass enough current to burn out any meter not able to carry 250 milliamperes or one-quarter ampere.

The maximum output of current from two half-wave rectifier tubes may run as high as 200 mils if any shorts or grounds exist in the apparatus. Under normal conditions, with a large receiver connected to the power amplifier, the total current at the center tap of the power transformer may run as high as 100 to 125 mils. When it comes to measuring the current flowing to amplifier tube plate circuits it is desirable to get fairly accurate indications as low as five mils. From these statements it may be seen that a milliammeter with several ranges or with several separate "shunts" is desirable.

When suitable ranges are not available on the milliammeter, a simple expedient may be used to get comparative readings. This scheme will also insure the meter against damage or burnout in case of severe overloads in the circuit tested. The meter should be shunted with an adjustable resistor as in Fig. 12. This resistor should be capable of carrying one-quarter ampere of current and should have a very low resistance, five or ten ohms being ample.

Before the meter is connected in the circuit to be tested, the resistor arm should be moved to position "b." Current will then flow from the circuit, through the resistor arm and to the other side of the circuit. The meter is short circuited by the resistor arm. With cur-

rent flowing for test, the arm is gradually moved toward position "a," which places the resistor (acting as a shunt) in parallel with the meter. The circuit current will divide, most of it flowing through the meter with arm in position "a," while for intermediate positions there will be a division of current proportional to the part of the resistor in the circuit.

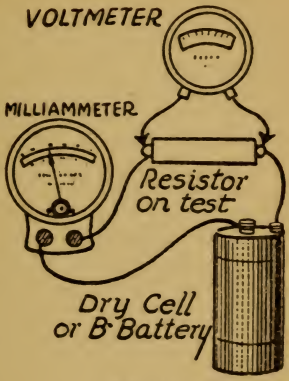


FIG. 13

A known small current, one surely within the range of the meter alone, may be measured with the meter while disconnected from the resistor. The same current may then be measured with the resistor connected and with its arm in position "a." The ratio of current indicated by the meter to the known current flowing will hold approximately true for other and higher values of current. The meter and resistor combination may be thus approximately calibrated for any position of the arm. This arrangement allows the use of a low reading meter with

comparatively large currents and avoids danger of running the meter pointer off its scale.

21. The 110-volt, 60-cycle line should then be connected and the meters observed. If any readings are seen to go off scale, the supply should immediately be disconnected. If the meter needle works backward the connections to the meter should be reversed. If any meters fail to read or read more than they should, the presence of defective apparatus or wiring is indicated. If the plate current in the amplifier tubes is found to be excessive, and yet the rectifier tubes continue to function properly, it is quite likely that the grid circuit of the amplifier tubes is open circuited. It is supposed that the audio frequency transformers already have been tested, but under these circumstances it would be wise to test them again, especially the one in the grid circuit of the offending tube.

22. If this is done and found to be continuous, and the wiring upon close examination found to be correct, then the grid bias resistor should be tested with battery and voltmeter to show whether or not it is open circuited. If it is found to be continuous, then the resistance value should be checked. In the great majority of cases, the resistors are correctly marked, but if the marking is correct and it is properly wired into the circuit, if it falls under suspicion its resistance should either be measured or it should be replaced.

23. A very simple but quite accurate method of measuring the resistance of the unit is by the application of Ohm's law, that is, that the resistance in ohms is equal to the voltage divided by the current in amperes. One milliampere equals .001 ampere.

24. The resistance in ohms of any resistor may be determined with the connections shown in Fig. 13. The battery, the milliammeter and the resistor to be tested are first connected in series as shown. This meter should be capable of reading a voltage at least as high

as the battery voltage. Before completing the last connection in this circuit, the wire end should be lightly flicked across the terminal to which it will connect and the meter's pointer watched. The pointer should not move off its scale. If the pointer deflection is excessive, the resistor may be short circuited or it may be of too low resistance for the battery voltage being used. If the meter's pointer remains on the scale, it is next in order to connect the voltmeter as shown.

To determine the resistance, the indicated voltage should be multiplied by 1000 and the result divided by the number of milliamperes flowing. The result is in ohms. Thus, with a voltage of 10 and a current of 5 mils, 10,000 would be divided by 5, giving 2,000 ohms as the resistance.

25. If no trouble is found in any of the above and still the tube is not functioning properly, then the circuit should be very carefully checked to make certain that there is not some remote portion which, in effect, short-circuits the grid bias resistor. Such an occurrence is quite possible, especially if the filament supply winding for the tube in question is used to supply other tubes as well. This would be particularly true if the other tubes used different grid bias.

26. Assuming it is none of these, there remains only the possibility that the grid in the tube itself is in contact with the filament or the socket short circuited.

27. The above hints apply most generally to the last stage of the amplifier. This is the high voltage stage and errors in it will be far more apparent than in the lower voltage stages. However, the other stages should not be neglected. If possible, their plate current should be determined, their plate voltage, their grid bias voltage, and in extreme cases, their filament voltage. If meters are not to be had, then we must depend upon the speaker and input to tell us whether or not the

amplifier is functioning properly, except for effects which would have been evidenced before this in our inspection.

The connections for meters measuring plate current, plate voltage and grid bias are shown in Fig. 14. To measure plate current, disconnect the wire from either the plate supply terminal "B" of the transformer following the tube or from the plate terminal "P" of this transformer or from the plate terminal of the tube

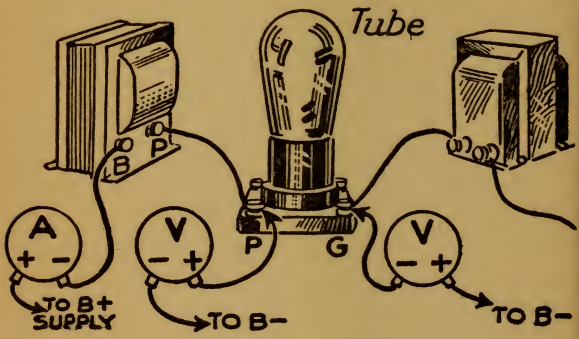


FIG. 14

socket. Connect a milliammeter between the end of the wire removed and the terminal from which it was removed with the positive terminal of the meter away from the tube or away from the transformer as shown.

To measure plate voltage, connect the positive side of a high resistance voltmeter to the plate terminal of the tube and connect the negative side of the meter to one of the filament terminals on the socket. Do not open any connection for this test.

To measure the grid bias voltage, connect a high

resistance voltmeter between the grid terminal of the tube and one of the filament terminals. Connect the negative terminal of the meter to the grid and the positive terminal to the filament terminal in this test and do not open any connections while making the test.

28. Assuming that there is nothing to be observed which would direct suspicion to the lower voltage stages, the speaker should be connected to the output system. (At this point the amplifier should not be connected to the receiver.) A very noticeable hum should be heard. The intensity of hum will depend upon whether or not the amplifier is functioning properly. If the hum is excessive, and does not diminish greatly when the primary of the first audio frequency transformer is short circuited, or if there is no hum, there is some part of the amplifier which is defective. The primary of an audio frequency transformer may be shorted by touching its two terminals, marked "P" and "B," with the two ends of a short piece of wire. No connections need be removed from these terminals for such a test.

29. If no hum is heard the grid terminal of the last amplifier tube should be touched with the moistened finger. Be extremely careful that it is the grid terminal and not the plate terminal which is touched on account of the extremely high voltage. If this action does not produce a hum, then the output system should again be carefully checked to be certain it is not open. Another good test to apply to the output transformer and speaker is to use a 4½ volt battery and momentarily connect it across the plate (P) and battery (B) terminals of the transformer. At the moment of contact, there should be heard a click in the speaker. The same should be heard at the time the battery is disconnected.

30. If the output stage is found to be satisfactory, and if short-circuiting the primary of the transformer immediately preceding the output stage gives a pronounced

reduction in hum—then the grid terminal of the first audio frequency transformer should be touched with the finger and a very definite response in the speaker should be heard. If this is found to be true, then the primary terminals of the first audio frequency transformer should be shorted, whereupon there should be another reduction in hum, very noticeable although not so great as that obtained when the primary of the second transformer was short-circuited.

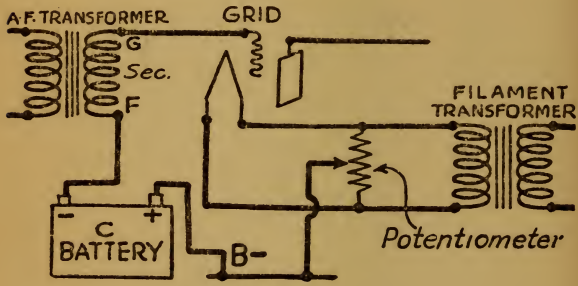


FIG. 15

31. At this point the amplifier should be connected to the receiver or phonograph pick-up. It is very important that proper connections be made. In the case of a power amplifier having but a single output stage and one power amplifier tube, the connecting plug should be inserted in the last audio frequency tube socket of the receiver. In the case of the push-pull output stage, the plate terminal on the input transformer of the power amplifier should be connected to the plate terminal of the first audio frequency tube socket in the receiver, care being taken to remove any connections which may already exist on this plate terminal.

32. In the case of a complete 2 or 3 stage amplifier, the plate of the detector tube in the receiver is connected to the plate terminal of the input transformer of the power amplifier. This connection must be made without disturbing any radio frequency chokes or bypass condensers which may be in the plate circuit of the detector tube. The plus-B terminal of the input transformer on the amplifier should be connected to that portion of the voltage divider which will provide normal voltage for the detector tube. If the receiver was originally equipped with an audio amplifier, the primary of the first audio coupler should be disconnected. All of these connections between the receiver and the power amplifier are clearly indicated in the pictorial and schematic diagrams for the various types of amplifiers.

33. In the matter of connecting a single output stage into the receiver, care must be exercised in completing the grid circuit of the last audio stage. In case C-battery terminals are provided in the receiver for C-battery use on the last stage, the minus-C (Power) terminal should be connected to the plus-C terminal of the receiver in order to complete the circuit.

34. Connections for the voltage supply for the remainder of the receiver should be made to the proper places on the voltage divider or to the provided binding posts. Again the importance of a good high resistance voltmeter is seen. If variable voltages are not available and if the drain of the set is heavy, it is very likely that the performance of the receiver may suffer by reason of reduced potentials. The obvious cure for this is to determine the extent of the voltage drop and take steps to remedy it if performance suffers. This may be done by either substituting a resistor unit in the section responsible, or shunting the fixed resistor with another resistor of suitable value which will provide variable voltages. The value of this shunt resistance is depend-

ent upon so many factors that unless one is familiar with such matters and has the necessary measuring instruments, its use should not be attempted except upon advice from some capable person.

35. The minus-B connection is very important in any amplifier. Even though the B supply from the amplifier is not used to operate the receiver, a minus-B connection must be made between the set and the power amplifier so that the grid circuit of the first amplifier

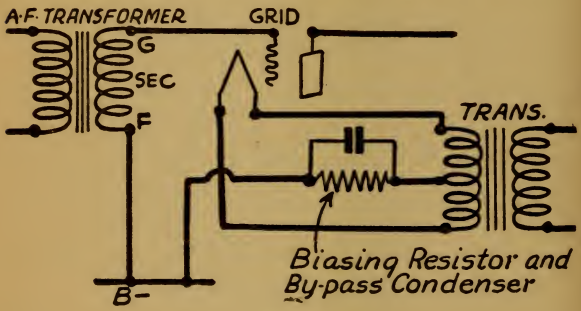


Fig. 16

tube will be provided with a return. Much trouble arises in audio amplifiers because of failure to complete the grid circuit for each tube. Should there be no output to the speaker or should the output be heard only on powerful stations and then as weak, thin music and rasping speech, the grid circuit may be suspected.

In Fig. 15 is shown a grid circuit used with a filament transformer having no center tap but fitted with a center tapping potentiometer either at the transformer or at the filament terminals of the tube. Beginning at the grid terminal of the tube, the grid circuit passes

through the secondary of the audio frequency transformer to the negative terminal of a C-battery, through the C-battery to a B-minus or grounded line, through this line to the center of the potentiometer, through the potentiometer, the filament transformer secondary and to the tube filament. It always must be possible to trace a grid circuit from the grid terminal of the tube back to the filament or cathode of the same tube, otherwise amplification will not take place.

In Fig. 16 is shown a grid circuit used with a center tapped filament transformer and a biasing resistor in the center lead. The grid circuit passes from the tube grid through the secondary of the audio frequency transformer to a B-minus line. From B-minus the circuit passes through the biasing resistor and the secondary winding of the filament transformer to the tube filament. In any grid circuit is must be possible for direct current to flow from the tube grid, through the grid circuit to the tube filament or cathode. Direct current does not flow through condensers, therefore this circuit must be completed from grid to filament or cathode by means of a complete metallic or conducting path.

In Fig. 17 is shown a grid circuit used with a center tapped filament transformer and with the grid bias secured from a voltage drop through a voltage divider on the plate power supply unit. The grid circuit passes from the tube grid, through the secondary of the audio frequency transformer to the C-minus terminal on the plate power unit. This circuit then passes through resistor "R" in this unit, to the B-minus terminal and through the secondary winding of the filament transformer to the tube filament or cathode.

Other variations may be found, but in every case it must be possible to trace the grid circuit through its return to either the tube filament or cathode. In heater

type alternating current tubes the cathode, marked "K" on the socket, forms the end of the grid return.

36. Wherever it is imperative that the plate voltages of the radio frequency and detector tubes be maintained at a constant value, the use of a voltage regulator tube, frequently called glow tube, is recommended. This tube provides an optional path for the plate current, customarily between the 90-volt and B-minus terminals. When

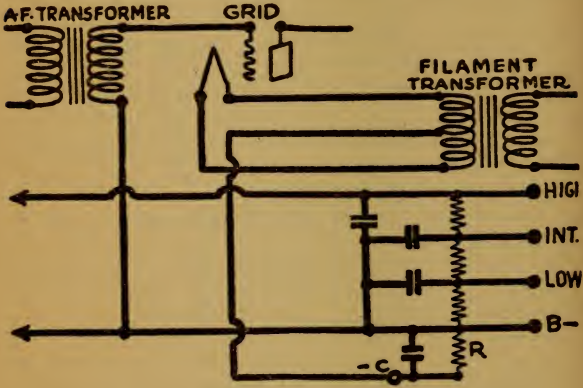


FIG. 17

little or no current is consumed by the receiver, the carrying capacity of the regulator tube is increased. On the other hand, when the amplifier is used with a receiver of heavy plate current drain, very little current flows through this tube. Thus, by insuring a constant current consumption, the voltage delivered by the protected portion of the plate supply is also maintained at a constant value regardless of reasonable variations in plate current consumption. When a voltage regulator

tube is employed, the high voltage side of the tube should be bypassed to B-minus through a 4.0-Mfd. condenser.

If a glow tube is incorporated in the amplifier, it is important that the voltages be so adjusted that the glow tube will not cease functioning. There must be a perceptible glow in the tube in order to receive any benefit from it. If the glow tube does go out, it is necesary either to decrease the set drain, which obviously is usually not desirable, or to increase the voltage applied to the tube by reducing the resistance in that part of the divider between the grid terminal connection to the glow tube and the high voltage end of the divider. The tube should under no condition be removed from the socket while the amplifier is in operation.

37. The determination of the source of hum is much more difficult than the determination of wrong voltages, chiefly because we have no common instrument for measuring it. About the only methods available are elimination and substitution. Various operations must be performed upon the apparatus and circuit until the troublesome factors have been located. By exercising a little patience and carefully following instructions it is possible to reduce hum to a point which approximates complete elimination.

38. If alternating current tubes are used elsewhere than in the output stage, it often happens that the relationship of the plugs which are inserted into the 110-volt, 60 cycle supply have a decided effect upon hum. Both the power supply transformer plug and the filament supply transformer plug should be turned over to determine the combination which gives the least hum.

39. The probable location of the hum may often be determined by shorting out the primaries of the audio coupling transformers. It is best to start at the speaker end of the amplifier. If there still exists a considerable

hum when the primary of the input transformer to the output stage is shorted, either the plate current is not sufficiently free from an alternating current component, the center tap of the filament winding is too far out of balance, the grid bias resistor bypass condenser is insufficient, or there is far too much stray field pickup by the coupling transformer to that stage. It is presupposed here that the voltages have all been checked. If this is not the case, then it is also possible that the value of the grid bias resistor is not correct.

40. In regard to the presence of an alternating current component in the plate current supply, the cause may be defective rectifier tubes; a short circuited choke coil; a choke coil through which the current exceeds the rating and vitiates the inductive effect; coupling between the power supply transformer and the choke coil (if the units are shielded and separated a few inches this is very improbable); alternating current supply to the filament or power supply transformer which has a high noise factor, poor wave form, changing frequency, or bad harmonics; open or leaky filter condensers or filter condensers of insufficient capacity.

41. If there is any reason to suspect the rectifier tubes, that is, if they are old or if they have suffered abuse, one or both should be replaced by new tubes.

42. The choke coil may be tested for lack of efficiency in stopping hum by shorting out first one section and then the other. When this is done, the hum should increase. Great care should be exercised when this is being done because of the very high voltages involved. *A very good habit to acquire is to disconnect the amplifier from the 100 volt supply before making any changes or tests upon the amplifier,* and to reconnect the supply after test connections are in place.

43. It is possible to estimate the probable current consumption of the amplifier from the list of tabulated

data. This should be very carefully checked and the rating of the choke coil compared with it to make certain that the current rating is not being exceeded. In the event that the choke is overloaded, a larger choke coil should be substituted.

The current flowing through the chokes may be roughly estimated as follows: Add together the normal plate currents for all tubes handled from the amplifier, including the power tube or tubes, other tubes in the amplifier and tubes in the receiver. Then add to this sum a steady voltage divider drain of 20 milliamperes. If a glow tube is used, add another 25 milliamperes. The sum total of all these loads is approximately the current flowing through the chokes.

44. With an exceptionally sensitive receiver, an exceptionally efficient speaker installation, or with certain other unusual conditions it may be found that a hum comes through the filter system because of a slight remaining inductive coupling. Such conditions may be handled by installing an additional filter circuit between the original filter and the voltage divider as shown in Fig. 18. This extra filter will consist of a double choke and a set of filter condensers identical with those used in the original filter.

45. If the 110 volt A.C. source (the power coming into the building) is not nearly pure 60-cycle sine wave energy, it is very difficult to obtain satisfactory operation from the amplifier. The noise sometimes can be reduced by grounding the minus-B of the amplifier. At times, the connection of the minus-B of the amplifier through a one mfd. condenser to one or both sides of the 110-volt line will be beneficial. With the exception of these possibilities, nothing more can be done unless the alternating current supply can be purified in some manner. Hum due to 110-volt supply irregularities is usually evidenced by a pitch higher than 60 cycles.

When the hum is a pure 60-cycle note, it can be quite strong in actual energy and still not be objectionable to the ear. This is not the case with impure supply. Such disturbances are rather high pitched, and are objectionable even when the amount of energy involved is small.

46. In some localities the line voltage is consistently higher than its normal rating. To overcome the harmful effect of this condition an adjustable resistor may be inserted between the incoming line and one side of the power transformer's primary winding. The resist-

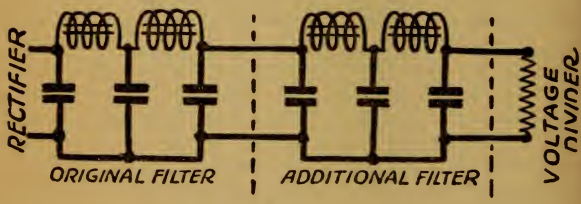


FIG. 18

ance may then be adjusted to lower the primary voltage. Such a resistor must be capable of carrying two amperes and of dissipating 50 watts.

Low line voltage cannot be compensated for in any simple manner. It is fortunate that a voltage below normal will do no harm to tube filaments nor to filter condensers, although a high voltage will shorten the life of both.

47. The presence of poor filter condensers can usually be found by disconnecting one section at a time and noting the increase in hum. The removal of a condenser from the filter circuit should be very apparent if it is functioning properly. In case it is not, a good condenser should be substituted for the defective one. *Great*

care must be taken to have the 110-volt supply disconnected when making such changes. Before handling condensers one should always be certain that they contain no charge because high capacity condensers are capable of inflicting severe shocks. It is always well to short-circuit the condenser terminals before handling if there is any possibility of the condenser being charged. The presence of insufficient capacity in the condensers may also be determined by increasing the capacity of one or more sections, when improved operation indicates an original capacity too small.

48. To determine whether or not the center tap of the filament winding is causing the disturbance, the center tap lead should be disconnected and connected to the movable arm of a 400-ohm potentiometer, the sides of which are then connected across the ends of the winding. The arm should be adjusted for position of minimum hum. If this minimum is less than the amount heard when the center lead is connected to the center tap of the transformer, either the transformer should be changed or the potentiometer should be used for center adjustment.

49. Bypass condensers across grid bias resistors always have a stabilizing influence on grid bias voltage which greatly improves tube performance. However, in some positions their presence or absence has little or no effect on hum. To determine whether or not such condensers are functioning properly they should be disconnected and the hum noted. If there is no change the condenser should be tested as outlined in paragraph 9.

50. The presence of inductive coupling between the filament supply transformer or the power supply transformer and the input transformer to the last stage may be determined by slowly rotating the input transformer and noting any diminution in hum. Hum from this cause will be decreased by moving the input transformer

farther away from the power supply transformer, or by placing the input transformer so that the core is at right angles to the field of the power supply and filament transformer.

51. It is often beneficial to connect all transformer and condenser cases to minus-B. If hum is originating in coupling between transformers this practice will aid materially in its reduction.

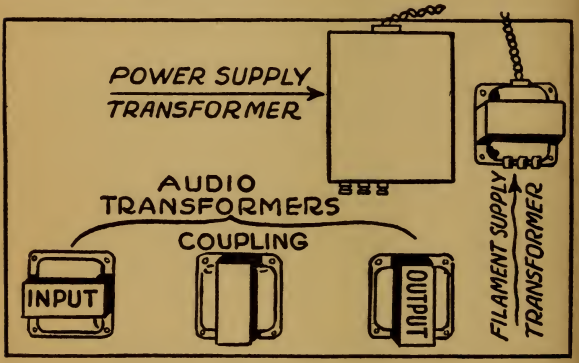


FIG. 19

52. During all of these tests (paragraphs 38 to 56), it is well to keep the primary of the audio frequency transformer short circuited, except the test for coupling (paragraph 50), when the primary should be open.

53. In inspecting the grid circuit, the power should be turned off and the last audio tube removed from its socket. With a voltmeter and battery, it should be determined whether a circuit exists from the grid of the socket to both filament terminals. If so, replace the tube, turn on the power, and note the amount of

hum very carefully. Disconnect the power and connect the grid terminal of the socket direct to the center tap of the filament winding supplying these tubes. Connect the power, determine the increase, if any, in hum. If the hum has increased, it is probable that the grid circuit is correct.

54. With the grid circuit short-circuited in this manner, do not allow the 110-volt supply to remain connected longer than is absolutely necessary to make the hum comparison because the plate current to the tube will increase greatly and if allowed to continue for a long time will seriously injure it.

55. If there was no change in hum during the preceding test, the grid resistor is not functioning either because of mistakes in the wiring or a short circuit in the bypass condenser. The presence of improper value of resistor can be determined by use of battery and meters as described previously. These not being available, the resistor should be examined for markings and compared with the values shown on tabulated tube data sheets.

56. Exactly the same process should be applied to the first stage. It will also be noted that the amount of hum left in the amplifier when the primary terminals of the first audio frequency transformer are short-circuited will be in excess of the hum remaining when the same operation is performed in the last stage. However, even this hum should not be great and should not be objectionable if the first stage is functioning properly.

57. It will be found, however, that the position for minimum hum for the first transformer will be much more critical than that of the second. In most cases, if the power supply transformer and the filament supply transformers are placed at the right hand rear of the baseboard, and the input transformer at the left hand front, the first transformer should be in such a position

that its primary terminals will be along the baseboard instead of across it. In other words, the most convenient location of the output transformer and the second audio frequency transformer is such that their terminals are at right angles to a line joining the centers of the two transformers, while in the case of the first audio frequency transformer the terminals are parallel to such a line. This is shown in Fig. 19.

58. It is advisable to keep the rectifier tubes as far removed from the input transformer as possible, as the

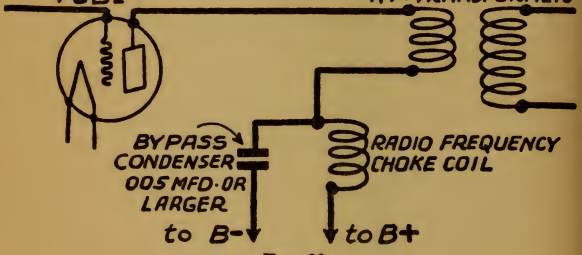


FIG. 20

field from these tubes acting on the first audio transformer often causes quite a substantial hum.

59. At times very peculiar behavior is observed in glow tubes. If the glow tube is operating near its critical temperature a particularly large drain may often throw the tube into a state of low frequency oscillation. This is more apt to happen if the glow tube is somewhat old. The remedy is either to secure a new tube or to increase the voltage upon the tube as was mentioned in paragraph 36.

60. If the amplifier is being used to supply a receiver which is rather sensitive, it is quite possible that the

origin of hum is in the set proper. If the amplifier itself is free from objectionable hum, then it is necessary to look to the receiver. Alternating current sets are liable to have hum of their own, and if this is not kept to the lowest possible point, it will be very annoying after it is amplified through two or more stages of audio frequency amplification.

61. It will be apparent that it is impossible to anticipate all possible sources of hum in a radio frequency amplifier. However, a few of the possibilities may be considered in a general manner.

62. All filament leads, if they carry alternating current, should be twisted conductor. There should be no tendency to oscillate in the radio frequency amplifiers as this will magnify the hum. Correct bias on the receiver tubes should be maintained. All plate supply leads should be heavily bypassed. Choke coils in the plate supply as in Fig. 20 are sometimes necessary. Proper operation of the detector tube at normal filament voltage is imperative. In this regard, it is usually found that plate rectification (a C-bias type detector) will produce less hum than grid rectification (grid leak and condenser type). In either case, however, the tube should have a normal plate current of at least one milliampere in order to load sufficiently the primary of the first audio frequency transformer.

63. If the receiver grid bias is secured by means of resistors, adequate bypassing is imperative. In aggravated cases of oscillation or "motorboating," the incorporation of the grid bias resistor in the glow tube circuit is often of material benefit. When this is done, the grid resistor must form part of the main voltage divider. Instead of being placed in the minus-B lead to the receiver, the negative-B to the set will be at a higher potential than the lower end of the divider, and the lower end of the divider will provide the grid bias

voltages for the receiver. Another advantage of this method of securing the automatic grid bias is that the grid bias voltage drop is not nearly so dependent upon the quantity of current flowing to the plates of the

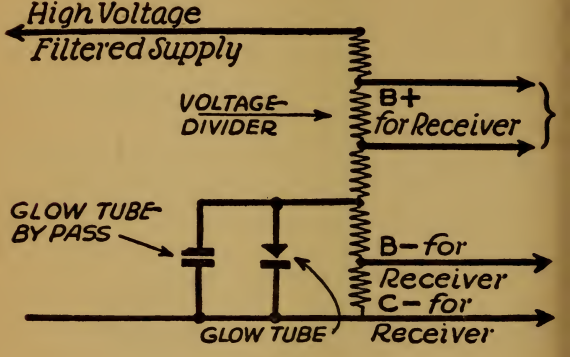


Fig. 21

tubes. The tendency to "motorboat" is greatly reduced. See Fig. 21.

64. When Raytheon B.H. rectifiers are used it is rather difficult to determine trouble from the rectifier tube itself unless meters are available. About 300 volts are ordinarily applied to the plates of the rectifier tubes and the current in the rectifier circuit is determined by the drain of the amplifier. This should not exceed the rating of the rectifier tube. If voltages are found to be correct and yet there is reason to suspect the rectifier, the most satisfactory way of determining whether or not the Raytheon tube is functioning properly is to replace it by one that is known to be good.

65. In cases where the field of the dynamic speaker

is incorporated in the voltage divider it is advisable to provide additional bypass capacity to the minus-B of the divider if there is tendency to oscillation or feedback. This is shown in Fig. 22.

66. It is very important in constructing any piece of radio apparatus to carefully determine beforehand just what the requirements are to be and then to choose apparatus that is designed specifically for such requirements. In view of the fact that in power amplifiers real power is being handled, this precaution is doubly important. In case there is doubt, someone capable of analyzing the situation should be consulted. Practically

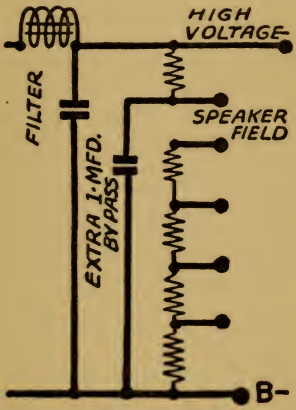


FIG. 22

all radio apparatus for power amplifiers is very definitely marked and it is extremely essential that the markings be carefully noted.

67. It would be extremely unwise to use a transformer

which was designed to operate two 250 tubes to operate one 210 tube, and vice versa. The same is true of the filter and bypass condensers. Condensers are made to withstand certain voltages and if these voltages are exceeded the condenser cannot be expected to stand up under the abuse. Certain definite values of resistance are necessary in order that the units may function satisfactorily, that they may not pass too much current and yet that they may pass sufficient. Resistance units are rated according to the amount of current they can safely carry and it is not fair to the manufacturer to overload the units.

68. Coupling transformers are designed for definite purposes and it is extremely unwise to use transformers for any purpose than that for which they are specified. There is a certain definite plate current that coupling transformers can handle and still maintain their characteristics. If this plate current is exceeded the transformer will no longer operate as it should. In case trouble is experienced in the power amplifier, one of the most important things to do is to consult the list of transformer data to be certain that the transformers are being used exactly as they were intended.

PICKUP DEVICES

TROUBLES occur in pickup devices as well as in other parts of the equipment. In some respects the difficulties in electro-magnetic pickups are similar to those encountered with other units which contain a coil of wire. In addition, however, several new items present themselves. As a point of interest in order to clarify existing miscomprehension, pickup devices of the above nature do not require a steady D.C. operating potential.

Pickup troubles in general are attributable directly to the use or to its mounting. Classified these troubles would be as follows:

Distortion—Worn out needle. Excessive tension upon tone-arm. Excessive tension upon armature. Loose needle. Loose elements. Defective damping (rubber pads).

"Dead" Unit—Frozen armature. Armature out of alignment. Open winding. Open connecting cable. Shorted winding. Shorted connecting cable. Open transformer primary.

Sputtering—Loose needle. Loose armature. Loose connections.

Unsteady Reproduction—Non-uniform speed of motor. Excessive weight upon disc.

Photo-electric Cell—In respect to photo-electric cells the considerations are less numerous. However, the items of importance cover a field external of mechanics. Due to the operating characteristics of the cell and the system, correct polarizing voltage governs not only intensity of the sound but also distortion. The subject

of the correct polarizing voltage is a matter depending entirely upon the photo-electric cell. Some cells require higher voltage than others, but in any case the correct voltage is specified and must be adhered to. Excessive voltage will impair the operation of the cell because it will ionize the cell causing distortion as well as a reduction in the signal output. Prolonged operation at excessive polarizing potential will injure the tube and increased signal output should not be attempted by increasing the magnitude of a polarizing voltage. If it is irreparable injury to the photo-electric cell will result.

On the other hand, insufficient potential will reduce signal output and will cause distortion. With respect to the actual potentials applied, that is at the tube element, one must consider that electrical unit which is located in the anode circuit of the cell; a resistance in the case of Western Electric System and a transformer winding in the case of RCA installations. Any defects in these devices, particularly in the former will influence the voltage at the cell elements. In addition to voltages one must consider the possibility of noises. Defective coupling elements will create noisy operating conditions. In this connection one must also include the battery which supplies the operating potentials. As a point of information we make the statement that normal battery voltage measure at the battery is not a positive indication of the fact that the battery is perfect.

We shall at this time work backwards. A clean window free of all finger prints goes a long way towards perfect maintenance of the apparatus. Any dirt of this kind will decrease the amount of light incident upon the active surface within the cell and since the effect of this light is to produce a voltage in the output circuit of the cell one can readily appreciate that every particle of dirt, smudge or other similar form of interference will create

a reduction in the amount of sound output and possibly cause distortion.

The photo-electric cell as a unit is allied with the exciting lamp and the optical system. Consequently permanent correct location of the cell relative to its position with respect to the remainder of the system is quite important. In this connection we cannot overlook the method of mounting. Freedom from vibration is paramount. If the cell is allowed to move it will create disturbing sounds of varied nature. Recognizing an emergency, an extra supply of photo-electric cells is important, changing the cell is within the province of the projectionist.

Cleanliness is a virtue and it must be applied to the film in general and the sound track in particular. Appreciating that only a small portion of the actual light impinged upon the film is transferred to the cell one need not be a technician to realize that any foreign interfering matter upon the sound track will reduce the light transmitted through the film and impinged upon the cell.

Optical System—Much has been written relative to the optical system. This arrangement of lenses and the slit is of infinite importance with respect to the successful operation of a sound motion picture system. However, its adjustment is a matter of microscopical mechanical alignment. We in line with others definitely state that the optical system should not be handled. If repairs are to be effected call the service man.

Exciting Lamp—The exciting lamp is the source of light in the sound head and because of its alliance with the optical system certain conditions must be fulfilled. First and foremost is cleanliness of the bulb. Prolonged operation of the filament has a tendency to deposit carbon film upon the inner surface of the glass bulb. Such a film interfers greatly with the transmission of light

hence an exciting lamp with the slightest discoloration should be discarded because it will create a loss in sound output. The tendency to overcome this decrease in sound intensity by increasing the filament current should not be applied because it will invariably result in burnout of the filament and interruption of a program in its midst. With respect to filament current the design of the filament employed in the exciting lamp is of such nature that it may be operated at some value less than the rating consistent with normal sound output. As a point of information, Western Electric lamps are rated at 3.6 amperes and RCA lamps are of two types rated at 5 and 7.5 amperes. The exact rating is usually marked upon the base of the lamp.

Supplementary to the filament current is the condition of the filament. Correct focus is imperative. Therefore normal position of the filament when the complete bulb is correctly located is quite important. Lamps with sagging filaments should be discarded. Rigid mounting must be attained and freedom from vibration is also of importance if disturbing noises are to be minimized. Referring once more to filament current while it is possible to operate at some value less than the rated value a steady value at any one figure is imperative. If for some reason the intensity of the exciting lamp is allowed to flicker fluttering of the sound will be the effect.

"B" ELIMINATORS

TROUBLES in B battery eliminators are usually of similar type regardless of the type of rectifying element used. Concerning ourselves with the conventional B eliminator operated from an A.C. source and employing a rectifying device we find the possible troubles to be

1. Insufficient output current and voltage.
2. Excessive hum in the output.
3. Dead eliminator.
4. Poor design.

It stands to reason that each of the above faults has a number of contributory causes, for example

1. Insufficient output current and voltage may be due to:
   a. Low line voltage.
   b. Defective rectifier tube or element.
   c. Excessive voltage drop in filter system.
   d. Insufficient voltage input to rectifier.
   e. Excessive load upon the eliminator.
2. Excessive hum in the output.
   a. Low line voltage.
   b. Defective rectifier tube or element.
   c. Shorted filter choke.
   d. Poor filter condensers or defective filter circuit.
   e. Lack of bypass condensers.
3. Dead eliminator.
   a. No line voltage.
   b. Defective transformer.
   c. Defective rectifier tube.
   d. Open filter circuit.
   e. Shorted filter circuit.

4. Poor design.
   a. Incorrect transformer-rectifier combination.
   b. Wrong rectifier.
   c. Incorrect filter unit constants.
   d. Lack of bypass condensers.
   e. Imperfect contacts.

Generally speaking troubles in amplifier are singular with respect to numbers and the same is true in the B eliminator with one exception, the possibility of a damaged rectifier due to overload when a filter condenser "blows" in operation. In all other cases of trouble it is safe to assume that the trouble is singular. Now, the list of troubles enumerated upon the preceding pages does not signify that, that list includes all the troubles, since each may involve additional items. Then again the presence of one fault or a fault of a certain type may eliminate all other faults as the possible reasons for the trouble on hand. To probe for these troubles we must be able to recognize symptoms and to do so, it is necessary to discuss the function of the various units in the eliminator, at least the important items. This discussion is necessary because many of the phenomena which might cause trouble are not evident upon the surface.

Since the output voltage is a function of the input voltage it stands to reason that the line voltage must be correct. If the line voltage is low, or the tap is incorrect, the A.C. voltage fed to the rectifier will be low. In turn the rectifier output will be low. This is true with all types of rectifiers.

If for some reason a part of the transformer secondary is shorted so that the required amount of turns are not in service, the output voltage (A.C.) fed to the rectifier will be low and the rectifier output will be low.

Since the voltage input (A.C.) to the rectifier is of such great importance, it is easy to understand that the

tube used must be the correct one for the transformer and vice versa and that these two govern the voltage and current rating of the eliminator.

The operating life of the filament type of rectifier tube is governed by the electronic emission from the filament. If this is low, the current output will be low and the tube is defective. The equivalent is true in the case of the tungar-rectigon rectifier but in this instance, the trouble is also exhaustion of the gas within the tube and the lack of current carriers. In the dry disc rectifier, it is the film. In all three cases premature death of the rectifier element is hastened by the application of higher than normal potentials.

In connection with the filter system, experience has shown that the system plays a small role when the trouble is of the nature mentioned, since a high resistance contact in the choke circuit would greatly reduce the voltage output and filter condensers seldom develop partial shorts. A leak across the filter condenser is possible and in this case a certain amount of energy would be lost in the filter system and the output would be reduced.

The design of the voltage divider network is of importance. A certain amount of bleeder current flows through the resistances. This amount of current is in excess of the amount of current consumed by the tubes. If the bleeder current is excessive, because the resistance of the voltage divider network is very low, the excessive drain will reduce the voltage and current output. A short in the voltage divider network will cause an increase in the bleeder current, but this condition would also cause lack of voltage across one of the taps, hence an indication of what is at fault.

We made mention that the voltage regulation characteristic of the average B eliminator is such that an increase in plate current drain will reduce the output

voltage. This means that the current and voltage output of an eliminator may be low because the current load, represented by the number of tubes being supplied with plate potential are greater than the number permitted by the design of the eliminator, i.e. the rectifier element and the transformer.

With respect to the second form of trouble—excessive hum in the output, we find other important factors.

Once again the line voltage is important. Low line voltage interferes with the normal operation of the rectifier and causes hum. If the rectifier is defective because of old age or some other reason, it performs poorly and causes a bad hum. Here we find that troubles 1 and 2 are allied. If the hum is accompanied by low output voltage, it indicates the possibility of a defective tube. We do not wish to state definitely that the tube is at fault because one or two other items will cause similar conditions. However, if the voltage is radically less than normal and the input voltage is normal and the hum is bad—check the rectifying element.

The function of the filter system is to eliminate the A.C. ripple in the rectifier tube output so that the voltage across the voltage divider is pure D.C. If a short develops in the filter choke or chokes, the efficiency of the filter system will be reduced and a greater percentage of the A.C. ripple will find its way to the output.

The filter condensers play an important role in filtering, as a matter of fact, with respect to general performance. If a condenser circuit is open, filtering is impaired and the hum is greater in the output. If one of the condensers is poor, filtering is impaired. The actual function of the various filter condensers will be discussed shortly.

The bypass condensers connected across the various sections of the voltage divider network are important with respect to hum in the output. They play a small

role in the actual filtering, but when correctly placed across the resistances, bypass the A.C. component in the output circuit so that it is removed from the D. C. supplied to the tubes in the amplifier. This applies equally well to all resistances in the voltage divider network, including the resistors utilized to supply the grid bias voltage and the resistances used to supply the filament potential.

The possible reasons for "dead" eliminators are very simple to understand. If the power transformer primary is open or the power line disconnected from the eliminator, voltage output is impossible, since A.C. voltage is not supplied to the rectifier. The same is true if the plate voltage winding or the filament voltage winding is open. If the rectifier tube filament is damaged operation is impossible, hence no voltage output. If the tube is defective, lack of gas in the gaseous rectifier, voltage output is impossible. If the filter condenser connected across the rectifier output is shorted, voltage will not be passed to the remainder of the eliminator. In this case heating of the rectifier will show that the rectifier is in operation. A short in any one of the filter condensers will make voltage across the voltage divider an impossible feat, since the shorted filter condenser is a short across the voltage divider. An open in the filter system will not permit passage of D.C. to the voltage output. We refer to an open in the choke circuit, or the fuse circuit in the filter.

A short in the bypass condenser network causes an effect very much different than the effect due to a short in the filter condenser system. A shorted bypass condenser will short one of the resistances or a portion of the voltage divider systems. Consequently voltage will not be available across the shorted resistance or section, but voltage will be available across the complete output, i.e. between the maximum B plus and the B minus or

the maximum C minus terminals. This is in direct contrast to the condition present when the short takes place in the filter condenser. When so located, voltage is not available across any of the sections of the voltage divider network, irrespective of the type of voltage divider.

It is easy to comprehend that a shorted section of the voltage divider will reduce the total resistance connected across the eliminator filter. As a result, the value of the bleeder current will increase and the increased current drain will reduce the total output voltage. Hence when the output voltage is less than normal and voltage is not obtained across one section of the voltage divider, it is an indication of a shorted section.

Lack of voltage across one section of the voltage divider is possible under another condition, namely when the voltage divider network is open. In this case the maximum output voltage increases rather than decreases, because an open in the voltage divider network removes the load across the eliminator, rather than increasing the current load.

With respect to the fourth designation—poor design—we have several very interesting considerations.

In the first place the output voltage and current are dependent upon the rectifier element and in turn the performance of the rectifier is governed by the operating potentials. It therefore stands to reason that the combination of transformer and rectifier must be correct, so that the operating potential applied to the rectifier be the correct potential. Insufficient potential will prohibit correct output from the rectifier, whereas excessive potential may injure the rectifier and if not injure the rectifier will greatly reduce the operating life. In this connection it is imperative that the maximum voltage (A.C.) rating be followed, as set forth by the rectifier manufacturer.

Interpretation of the above means that rectifiers cannot be applied in a haphazard manner. If a tube or an element is designed for a 350 volt (A.C.) input the tube or element should not be employed with a 280 volt input, because the rated current and voltage output will not be secured. On the other hand the tube or element should not be used with a 400 or a 450 volt input because the operating life of the tube or element will be greatly reduced and permanent injury will result. . . . We realize that many rectifiers are operated at A.C. voltages much higher than the manufacturer's rating, but shortened operating life is the usual result.

In order to comprehend troubles in B power units it is necessary to consider the action within the unit. That the filter system smooths out the pulsating D.C. output fed to it from the rectifier system is well known, but the action of the individual units within the filter system is not so well known. . . . It stands to reason that the electrical constants of the chokes and condensers constituting the filter must be of definite values in order that the correct effect be secured.

The fundamental frequency or the strongest frequency to be filtered was mentioned earlier in this section and as far as filtering is concerned, the average arrangement functions quite well, but the parts in the filter manifest an effect upon the operation of the eliminator in ways other than just the actual filtering. For example, the condenser nearest the rectifier system influences the voltage output of the rectifier, consequently the voltage output of the complete eliminator. In addition it influences the voltage regulation of the system, i.e. the change in output voltage per milliampere increase in current drain. In this connection the design of the chokes is of importance. The midsection condenser affects the hum in the system and is very important with respect to the elimination of the hum. . . . The output condenser in turn dis-

plays an effect upon the hum and also upon the quality of the signal made audible by the speaker. This condenser functions as a storage tank supplying the required power when a strong signal calls for additional operating power from the eliminator in order to permit the full plate current swing without reducing the available plate voltage. Conventional practice has standardized the values employed in the filter system. The input condenser is usually 2 mfd. although 4 mfd. is frequently used. The midsection condenser is 2 mfd. and the output condenser varies according to the likes and dislikes of the design engineer. This value varies between 4 and 10 mfd. the latter being preferable.

In certain cases the input filter condenser is omitted. The omission is based upon experimental data showing increased life of the rectifying element (filament type). However, many filament type rectifiers have been in use over normal periods where condenser input and the system is used.

The voltage drop in the filter system is usually the D.C. voltage drop across the filter chokes, since these units possess an appreciable amount of D.C. resistance. With respect to the chokes employed in such filter systems, it is necessary to consider the inductance of the choke when D.C. is passing through the winding. The rectifier output contains a large percentage of A.C. and the filtering action in the filter is secured by virtue of the inductance and capacity present in the circuit. If the electrical constants of units in the filter system have been selected because they perform the required work, and if for some reason the inductance values are reduced, the filtering action of the system is impaired and the hum in the output will be objectionable. It is for this reason that we state the importance of sufficient inductance in the filter chokes under normal load i.e., normal D.C. current flow through the chokes. Furthermore, the action of

the D.C. is to reduce the inductance of the choke and if the reduction is appreciable filtering is impaired.

Then again the current flow (maximum) through the choke must be within the rating of the choke, because excessive current flow will so affect the choke that undesired harmonics will be introduced in the filter system and appreciable hum will be present in the output. The above is the result of core saturation. The above is applicable with equal facility to all types of conventional B power unit filters, regardless of the type of rectifier employed.

One of the major troubles encountered with B eliminators has been voltage fluctuation and the method employed to overcome this difficulty has been the use of a voltage regulator tube, usually connected between the plus 90 and the B minus taps. The use of the tube permits the attainment of constant output potential at the 90 volt tap over a range of current load. Such a unit is represented by the 874 tube. This tube is used in some Samson Power Packs. In connection with this tube, one significant fact is overlooked, a fact which governs the successful utility of the tube. This fact is the current consumption of the tube. In other words, the tube requires about 30 milliamperes for normal operation and this drain must be added to the normal current load. If the normal current load exclusive of the voltage regulator tube is equal to the eliminator output or practically the eliminator output, the voltage regulator tube cannot be applied, because the tube drain will overload the eliminator and cause a reduction in output voltage.

This tube has been found advantageous with respect to the elimination of motorboating, but in that respect, similar effects were obtained with a condenser of about 20 mfds. although the replacement of the tube with the condenser had no material effect upon voltage regulation.

The bypass condensers in a B eliminator are important

because of the effect upon the amplifier. First they function to bypass whatever A.C. is left in the output so that it is not impressed upon the plate of the tubes in the receiver. Second they bypass each resistance so that the A.C. component (signal) is not caused to pass through the resistance to other plate circuits in the receiver, causing excessive regeneration, howling and motorboating. In many instances the omission of a bypass condenser across a section of the voltage divider resistance, particularly the detector section, will cause extreme howling. The bypass condenser is of extreme importance across the grid bias resistance, because it removes all effect of the resistance as a coupling resistance between circuits and minimizes distortion in the event that the A signal voltage causes a voltage drop across the C bias resistance in such phase with the signal voltage that some of the signal voltage (low frequencies) is balanced out.

The value of the condenser employed to bypass the grid bias resistance has been found to be very important with respect to regeneration in the audio amplifier and hum in the complete system. All together too many installations empty low values of bypass capacity across the grid bias resistances in the system. A condenser with a reactance value of 1666 ohms at 60 cycles is of very little use as a bypass condenser across a 300 ohm resistance, since the hindrance offered to the flow of A.C. through the circuit is greater in the condenser than in the resistance, hence more will flow through the resistance into the circuit, than will flow through the condenser. In very many instances, each increase in bypass capacity diminished the magnitude of the hum in the output.

Before closing this section, we cannot help but make mention of two significant items, the operating voltage rating of the condensers in the power unit and the current carrying capacity of the resistances. The small condensers employed as buffer condensers in eliminators

employing the gaseous rectifier are subjected to A.C. potentials from the transformer winding. Consequently the operating voltages rating of these condensers lies within the A.C. category. Now, A.C. voltages are of two classifications, effective and peak, the former being the value indicated on an ordinary A.C. voltmeter and the value actually useful for work. However, the peak voltage is of importance when condensers are in the circuit since they are subjected to the actual peak voltage which, in value, is equal to the

$$\text{effective voltage} \times 1.414$$

Hence the voltage impressed across the condenser is greater than the voltage indicated upon a meter connected across that A.C. winding. This means that the operating voltage (A.C.) rating of the condenser must be sufficiently great to withstand the peak voltage. If the transformer voltage is 350 volts (measurement by meter) the A.C. operating voltage rating of the buffer condensers should be at least

$$350 \times 1.414 \text{ or } = 495 \text{ volts.}$$

This data should be borne in mind wherever large value of A.C. voltage is involved, as a matter of fact whenever A.C. voltage is applied to condensers and the operating voltage rating of the condenser governs its operating life.

With respect to the resistances in the voltage divider network, overloading of the resistances will cause burn out and noise. As far as the current carrying capacity of the resistances is concerned, it is necessary to consider the position or the location of the resistance in the voltage divider system.

Shooting trouble in a power B unit is not difficult if the parts used in the system are accessible. As a matter of fact trouble shooting is simple. If, however, the unit

is not only sealed within a container, but the individual units are not accessible, the best thing to do is to call the service man. If the various units in the eliminator are contained in individual cans and are accessible for test by removing the cover, investigation of a defective unit is in order.

Suppose that the trouble is a "dead" eliminator or no voltage at the taps. What is the method of procedure? We shall enumerate the steps and diagnose.

Line Voltage—In order that voltage be supplied to the rectifier it is essential that voltage be supplied to the power transformer. The fact that the plug makes perfect contact with the line socket means very little. See that the line control switch is on, that the primary tap switch makes contact, and that the line fuses are perfect. Examine the rectifying tube or element. If it is warm, glowing, if of filament type it is unnecessary to check continuity through the transformer primary winding. If, however, the rectifier is not operating, check continuity through the transformer primary.

Transformer Output Voltage—Satisfactory primary circuit continuity does not mean satisfactory secondary circuit continuity. Perhaps the filament circuit is open. This should be checked by means of a voltmeter or a continuity tester across the filament terminals of the socket by means of a conventional plug insert connected to an A.C. voltmeter or by means of the continuity tester prongs connected to a voltmeter. It should be understood that this test is unnecessary if the tube filament lights and burns at normal brilliancy. The voltage check at the socket is not the complete test. If voltage across the filament terminals is lacking it is necessary to check the voltage at the transformer terminals or to check the continuity of the filament winding at the transformer terminals.

Lack of voltage across the output circuit, the voltage divider, may be due to two conditions in the filter system,

an open in the choke circuit or the B-minus return circuit between the B-minus or maximum C and the rectifier, and to a shorted filter condenser. A D.C. voltage test across the first filter condenser or across the input to the filter will show a shorted filter condenser and even an idea of its location; providing that the minus return circuit is intact, i.e., the lead between the B-minus or the C-minus and the minus terminal of the power transformer secondary.

A shorted input filter condenser will eliminate all possibility of D.C. voltage measure across the condenser. Furthermore, a short in this condenser will cause overloading of the rectifiers, which in the case of the filament type of rectifier will cause overheating of the tube plate. In the event that in a full wave system, employing two half wave rectifier tubes one plate overheats and the other appears to be normal, the defect is in the latter tube, the one with the normal plate.

If a voltage drop is found across the input to the filter and voltage is not available across the voltage divider, it is necessary to consider the voltage available across the input filter condenser. If it is low, it means that a heavy load is being applied to the rectifier system and this load is either a short between the choke and the minus side of the system or a punctured filter condenser between the input and the voltage divider. If the voltage reading is very high, it means that the choke circuit is open or that the circuit between the output choke and the maximum B plus is open, because either open will remove the load.

To locate the punctured filter condenser it is necessary to check the remaining filter condensers by measuring the voltage across the condenser. Voltage will be lacking across the punctured unit. Continuity in the choke system is checked with a continuity tester. This method of procedure is applicable to all type of B eliminators and is independent of the type of voltage divider employed.

Let us take another instance. . . . Voltage is not avail-

able across one output tap. The logical place to seek the cause of trouble is in the output circuit. This part of the eliminator includes the bypass condensers as well as the resistances in the network. Once again we must consider several factors. An open resistance will create one effect, whereas a shorted resistance will create another effect. Then again it is necessary to know the type of voltage divider structure.

When the bypass condenser is connected across one resistance, a short in the condenser is the same as a short in the resistance, but this circuit arrangement is not used in the B voltage systems. The only location of such circuit connection is the bypass condenser across the C bias resistance. This includes the C bias resistance and bypass condenser in the B eliminator.

Before we progress to other items we wish to make mention that all eliminators do not employ two chokes in the filter system and that in many cases when a dynamic speaker is employed, the filled coil of the dynamic speaker functions as a filter choke and is energized by the eliminator current.

Continuing with trouble shooting, let us imagine that the trouble is hum, in other words, excessive A.C. in the D.C. output. In many cases this condition exists with normal plate potential hence the measurement of voltage is of little value. . . . It is more important to examine the installation to see if all the condensers are correctly connected. Incorrect placement of a filter condenser will cause hum. A short circuited choke will cause hum, hence continuity test through the chokes will prove of advantage. In this respect, the regular continuity tester is satisfactory providing that the tester realizes that the chokes possess D.C. resistance and that full reading is impossible when the voltmeter-battery continuity tester is applied. Open circuits in the bypass condenser system will cause hum. . . . A reversed line plug will cause

hum. Lack of ground in systems designed for a ground will cause hum. . . . With respect to the chokes in the filter, continuity may be checked by deliberately shorting the choke or chokes. If circuit continuity is satisfactory, shorting the chokes should increase the hum. Disconnecting condensers should increase the hum.

In the event that the eliminator output voltage is low and the hum is present, other factors must be considered. If the hum and the low voltage are due to the same condition. Voltage will be available at all taps and across all circuits and circuit continuity with respect to the D.C. items is usually normal. The possible causes are low filter capacity or an open in the filter condenser circuit; low line voltage and defective rectifiers.

The eliminator is a possible source of noise. Voltage measurements are of little use in this respect and it is necessary to seek points of poor contact. This requires visual examination. Lack of ground may cause the noise because the electro-static shield in the transformer is not grounded. In many instances the noise is carried to the set through the complete eliminator and the source is the power system feeding the eliminator.

Overloaded voltage divider resistances will cause hissing and frying sounds and examination will show arcing if the resistances are wire wound. Settlement of dust and lint upon condensers will cause periodic flashover across the dirt. Insufficient separation between wires carrying high and low potentials may cause flash over. Overloading of the rectifier element or tube may cause intermittent arcing and noise. Defective rectifiers will cause noisy operation. In this case evidence of the trouble is found in the output voltage, the voltage fluctuating during the periods of noisy operation. Replacement of the rectifier with a new unit or tube is the best test.

SOUND EQUIPMENT

When it is found that there is no sound when operating with R.C.A. sound-film equipment, check the following:

1. Are the switches and rheostats set correctly? Check against "Starting With Sound Film."

2. Exciter lamp burned out? Turn another lamp in position.

3. "Film-Disc" switch set wrong.

4. "Fading Potentiometer" in the "Off" position or set for the wrong projector?

5. Voltage amplifier defective? Change to the other voltage amplifier.

6. Sound gate aperture dirty? Inspect the aperture through the photo-cell housing.

7. Photo-cell defective? Try a new photo-cell.

8. Power amplifier A.C. supply circuit defective—"Primary Voltage" meter on "O"? Replace the line fuses once if they are blown. See that the converting equipment (if used) is running.

9. Are the loudspeakers plugged in on the stage?

10. Short circuit on the storage battery line—all exciter lamps and voltage amplifier tubes out? Change to the other storage battery. Inspect the fuses of the 4-p., d-t. switch. If blown, test for the location of the short circuit as follows: Turn the "Battery" switch "Off" and disconnect the plugs on input control panel. Insert new fuses in the 4-p., d-t. switch. Turn the "Battery" switch "On" and reconnect the plugs on the input control panel one at a time. If the fuses blow when the "Battery" switch is turned "On," make same test with the other voltage amplifier in the circuit. The trouble is in the part

of the circuit which blows the fuses when connected. Operate without this part of the circuit if possible.

Low Volume with Sound Film—

1. Exciter lamp currents correct?

2. Storage battery discharged—exciter lamp currents need frequent readjustments? Switch to the other storage battery.

3. Exciter lamp out of focus? Make the card test. Turn another exciter lamp in position.

4. Sound gate aperture partly clogged? Inspect the aperture through the photo-cell housing.

5. Photo-cell defective—low volume on one projector? Use a new photo-cell if the other projector gives decidedly better results.

6. Voltage amplifier defective? Change to the other voltage amplifier.

7. One power amplifier defective? If the individual fuses of the power amplifier are blown, replace them once. If the plates of the rectifier tubes (UX-281) get red hot, turn the power amplifier switch "Off." Adjust the "Primary Voltage" meter reading to 100 volts.

Quality with Sound Film—

1. Poor sound film?

2. Dirty sound gate?

3. Dirty film?

4. Dirty constant speed sprocket?

5. One or more tubes of the voltage amplifier not lighted or defective? Change voltage amplifiers. Replace the defective tubes.

6. One tube of a power amplifier not lighted or defective? Replace the defective tube.

7. Loudspeaker out of adjustment? Hold your ear close to each loudspeaker. Cut out the defective loudspeaker by disconnecting the two plugs from it.

Film Breaks When Running Sound Film—The pic-

ture and the sound are always synchronized since the sound-record is on the same film as the picture.

1. Close the dowser.
2. Stop the projector motor.
3. Bring the "Fading Potentiometer" to the "Off" position.
4. Rethread the projector.
5. Start the projector motor.
6. When the motor attains normal running speed, open the dowser and bring the "Fading Potentiometer" down to its normal setting.

When the film is spliced, paint a half moon over the sound track splice if the film has a varying width sound-record. Paint a blunt apex triangle over the sound track splace if the film has a varying density sound-record. Use Zapon Concentrated Black Lacquer, No. 2,002-2.

No Sound with Record—

1. Are the switches and rheostats set correctly? Check against "Starting With Record."
2. "Film-Disc" switch set wrong?
3. "Fading Potentiometer" in the "Off" position or set for wrong projector?
4. Voltage amplifier defective? Change to the other voltage amplifier.
5. Pickup defective? Rub the needle with the finger. Try a new pickup.
6. Power amplifier A.C. supply circuit defective—"Primary Voltage" meter on "O"? Replace the line fuses once if they are blown. See that the converting equipment (if used) is running.
7. Are loudspeakers plugged in on the stage?
8. Short circuit on the storage battery line—all exciter lamps and voltage amplifier tubes out? Change to the other storage battery. Inspect the fuses of the 4-p., d-t. switch. If blown, test for the location of the short circuit as follows: Turn the "Battery" switch "Off" and

disconnect the plugs on the input control panel. Insert new fuses in the 4-p., d-t. switch. Turn the "Battery" switch "On" and reconnect the plugs on the input control panel one at a time. If the fuses blow when the "Battery" switch is turned "On," make the same test with the other voltage amplifier in the circuit. The trouble is in the part of the circuit which blows the fuses when connected. Operate without this part of the circuit if possible.

Low Volume with Record—

1. Storage battery discharged? Switch to the other storage battery.

2. Pickup defective—low volume on one projector? Use a new pickup if the other projector gives decidedly better results.

3. Voltage amplifier defective? Change to the other voltage amplifier.

4. One power amplifier defective? If the individual fuses of the power amplifier are blown, replace them once. If the plates of the rectifier tubes (UX-281) get red hot, turn the power amplifier switch "Off." Adjust the "Primary Voltage" meter reading to 100 volts.

Poor Quality with Record—

1. Poor record?

2. Dirty record?

3. Pickup defective on one projector? Use a new pickup if the sound of the other projector is all right.

4. One or more tubes of voltage amplifier not lighted or defective? Change voltage amplifiers. Replace the defective tubes.

5. One tube of a power amplifier not lighted or defective? Replace the defective tube.

6. Loudspeaker out of adjustment? Hold your ear close to each loudspeaker. Cut out the defective loudspeaker by disconnecting the two plugs from it.

Film Breaks Below Upper Feed Sprocket when

Running Record—The picture and the sound are still synchronized. Do not lift the pickup from the record.

1. Close the dowser.
2. Stop the projector motor.
3. Turn the "Fading Potentiometer" to the "Off" position.
4. Rethread the projector without taking the film from the upper feed sprocket.
5. Start the projector motor.
6. When the motor attains normal running speed, open the dowser and turn the "Fading Potentiometer" down to its normal setting.

When splicing film always keep the film of constant length by inserting a strip of black leader equal in length to the piece cut out.

Film Breaks above Upper Feed Sprocket when Running Record—The picture and the sound are no longer synchronized.

1. Close the dowser.
2. Stop the projector.
3. Turn the "Fading Potentiometer" to the "Off" position.
4. Rethread the projector.
5. Start the projector motor.
6. When the motor attains normal running speed, open the dowser. Leave the "Fading Potentiometer" in the "Off" position and run the film silent.

When splicing film always keep the film of constant length by inserting a strip of black leader equal in length to the piece cut out.

Needle of Pickup Jumps Groove on Record—The picture and the sound are no longer synchronized. Turn the "Fading Potentiometer" to the "Off" position. Run the film without sound. Inspect the tone-arm to see if it binds or catches at any point as the pickup moves

over the record. It is unwise to use a record again on which the needle has once jumped the groove.

Noise of Intermittent Sound with Either Sound Film or Record—

1. Dirt and acid on top of storage battery? Switch to another storage battery. Clean.

2. Gassing storage battery? Do not use a storage battery immediately after charging.

3. Loose storage battery terminal connection? Clean and tighten the terminal connections.

4. Loose connection on dry batteries? Clean and tighten the terminal connections.

5. Poor ground connection? Clean and tighten the ground connections.

Motor Stops when Running Either Sound Film or Record—Motor supply line open? Check the supply circuit switches and fuses. Replace the fuses once if they are blown. See that the converting equipment (if used) is running. Check the projector and sound mechanism for any hot bearings.

Motor Troubles—A few facts relative to motors have already been submitted. The following addenda is in connection with the Western Electric 700-A motor control cabinet. The motor employed in connection with the 700-A motor control box is provided with waste packed bearings which have been properly lubricated at the factory. On all operating schedule of three hours per day, the bearings will run for approximately six months without further lubrication. Every six months 10 to 20 drops of petroleum oil such as grade "A" Mobiloil should be added to each bearing. Do not use vegetable or animal oil. Care should be taken to avoid too much oil as it may get on the commutator and cause sparking.

Make sure that the brushes move freely in the holders and at the same time make a firm contact on the com-

mutator. Arrange the pigtails on the brushes so that the brushes will make proper contact. The top of the right-hand brush is marked "+" and the left-hand brush is marked "—" to serve as identification if brushes are removed for inspection. Keep an extra set of brushes on hand. Fit new brushes carefully to the commutator by means of sandpaper.

Keep the commutator clean and maintain its polished surface. Blow any dust from around the brushes and from the inside of the commutator end housing by means of some compressor or small air bellows. Do not use a lubricant on the commutator as the brushes are self lubricated. In case any oil gets on the commutator it should be wiped off and the slots between the commutator bars cleaned free of carbon dust. If the motor is operated in a damp place it is desirable to clean out the commutator slots at least once a month in order to prevent sparking.

Owing to the fact that there are no moving parts in the control box, there should be a minimum of trouble with the control box. However the following data is given in the event that trouble does occur and diagnosis is desired. The voltage of the generator delivered to terminals should be in the neighborhood of 27.5 volts at 720 cycles when the motor is running at the regulated speed of 1,200 r.p.m. The plate current through V1 should be between 1 and 2 milliamperes. The grid of the tube V1 should not draw any current. The grids of the tubes V2 and V3 should draw about 1 milliampere current when the space current read on meter M1 exceeds 60 milliamperes, and should draw no grid current whatever when the plate current read on meter M1 is less than 30 milliamperes.

Western Electric 701-A Motor Control—The voltage from the generator applied to the terminals 3-4 should be 5.1 volts $\mp$ 15%. This must be measured

by a high resistance voltmeter. The current through the field circuit 5-6 of the generator should be of the order of 20 milliamperes. The plate current of the detector tube V1 should be of the order of 1 milliampere after the set is running under regulated conditions and should be zero until the motor has reached the operating point. The rectifier tube V2 should deliver a voltage across the condensers C1 to C4 of approximately 400 volts. The tubes V3 and V4 should draw approximately 50 milliamperes plate current at the instant of starting and under these conditions the grids should draw a fraction of a milliampere. After reaching the operating point, however, there should be no grid current in the tubes V3 and V4.

No troubles should be encountered with the motors provided these units are given reasonable care and maintenance. The maintenance of these parts consists simply in a periodical inspection of the apparatus, care being taken to see that the machine is kept clean. The brushes should be removed and examined occasionally, and the bearings oiled. The brushes are provided with a curved surface to fit the curve of the commutator. When these are inserted in the brush holders care should be taken to make sure the brush surface sets properly on the commutator.

Troubles in Commutator Type Motors—Poor Speed Regulation—Fluctuation in motor speed, resulting in wobbling is attributable to improper operation of the governor and in many cases to fluctuating line voltage. The governor torque spring should be adjusted first, since the torque spring compensates for line voltage variation. Loosen setscrew on torque spring, adjust screw until there is very little pressure on the torque spring. Then operate the motor with the turntable in position, tightening the adjusting screw until a stable condition is obtained. It might be well during this op-

eration to load the motor by playing a record. In the event that such a condition has been present since the installation of the complete receiver, check all parts of the governor to locate faulty construction of the device. If this proves to be the case, the motor must be returned to the manufacturer. If the governor is intact and fluctuating speed is incident to each revolution, check the motor for open circuits in the armature. In some instances, periodic flashes under the brushes indicate open circuits; also carbonized spots between the commutator bars corresponding to the open coil.

Sparking—The possible reasons for excessive sparking at the commutator are quite numerous and every effort should be made to eliminate this form of trouble because of the effect it displays upon the operation of the amplifier when the motor is employed for electric pickup and reproduction of a record. Imperfect contact between the brush and the commutator due to poor brush springs or worn brushes will cause sparking and pitting of the commutator segments. A filter is employed with such types of motors to eliminate sparking and it might be well to check the action of this filter and the condition of the filter. Weak brush springs will cause non-uniform pressure of the brush upon the commutator with consequent sparking. Open armature coils within the motor, or opens at the commutator will likewise cause sparking. It is possible to repair the latter condition, but if the open is inside the motor, a complete new armature is necesary, unless of course, one wishes to rewind the coils.

A rough commutator will cause sparking and a ring of carbon will be evident around the periphery. The remedy is to clean the commutator with fine carborundum paper or sand paper. Garnet paper of the 8/0 grade is excellent for polishing the commutator.

Motor Noises—An imperfectly operating motor will

create numerous annoying effects, among which is an uneven hum of varying strength. Two conditions are apt to cause this effect. First is a turntable which does not run true and the second is a short in the armature winding. The latter, however, is in most cases also associated with low torque. The same condition may also be found if a winding is grounded rather than shorted. In some cases a loose bearing will cause a hum. This may be checked by pressing the side of the shaft. The correct condition is no play yet perfect revolution. With respect to the turntable, it might be well to remove the unit and check for imperfections of machining or for particles of dirt between the turntable and the motor shaft. A suggestion which has been found effective is to remove the turntable and to reset it in another position.

A rattling noise may be due to imperfect operation of the governor or foreign particles in the bearings.

Low Torque—Low torque or insufficient power on the part of the motor may be due to shorted windings as mentioned, either armature or field. If a field winding is shorted it is necessary to replace it with a new winding. Such repairs should be effected by one familiar with motor apparatus. If the short is at the commutator, between segments, it is possible to alleviate the trouble by clearing and polishing the commutator. Another condition which may cause such action is jamming of the motor shaft because of foreign particles in the bearings; sometimes insufficient lubrication. Provision is usually made for adjustment of the location of the bearings and end play of the shaft.

A stalled motor may be due to binding of the shaft at the bearings or some other part of the unit, insufficient lubrication or an open electrical circuit.

Filters—Simple capacity type filters find extensive utility in connection with such motors. The application

of such a device is shown below. One filter is intended for connection across the brushes whereas the other is for connection across the line input. Each unit consists of two condensers in series with the midtap connected to ground. Care must be taken to see that the working voltage rating of the condensers is such to withstand the potentials encountered in the circuit.

STORAGE BATTERIES

In the proper care of a storage battery if the following things are remembered you will escape 75 per cent of your battery troubles:

First—Test the specific gravity of all cells with a hydrometer two or three times a month. If any of the cells are below 1,200, the battery is more than half discharged, and it should be recharged.

Second—Pure water must be added to all cells regularly and at sufficiently frequent intervals to keep the solution at the proper height. Add water until solution is one-half inch above top of plates.

Never let solution get below top of plates.

Plugs must be removed to add water, then replaced and screwed on after filling.

The battery should be inspected and filled with water once every week in warm weather and once every two weeks in cold weather.

Do not use Acid or Electrolyte, only pure water.

Do not use any water known to contain even small quantities of salts or iron of any kind.

Distilled water or fresh, clean rain water only should be used.

Use only a clean vessel for handling or storing water.

Add water regularly, although the battery may seem to work all right without it.

In order to avoid freezing of the battery, it should always be kept in a fully charged condition. A fully charged battery will not freeze in temperatures ordinarily met.

Electrolyte will freeze as follows:

Sp. gr. 1,150, battery empty, 20 above zero F.
Sp. gr. 1,180, battery ¾ discharged, zero F.
Sp. gr. 1,215, battery ½ discharged, 20 below zero F.
Sp. gr. 1,250, battery ¼ discharged, 60 below zero F.

Therefore, it will be seen that there is no danger of the battery freezing up if it is kept at a specific gravity of from 1,250 to 1,300 and it should be kept as near 1,275 as possible. Under no circumstances should acid or electrolyte be added to the cells to bring them up to the required specific gravity. Nothing but pure water must be put in the cells after the battery has been once placed in commission and the specific gravity must be kept up by charging only.

General Storage Battery Data—A storage battery, secondary battery, or accumulator, as it is variously called, is an electrical device in which chemical action is first caused by the passage of electric current, after which the device is capable of giving off electric current by means of secondary reversed chemical action. Any voltaic couple that is reversible in its action is a storage battery. The process of storing electric energy by the passage of current from an external source, is called charging the battery; when the battery is giving off current, it is said to be discharging. A storage battery cell has two elements or plates, and an electrolyte. The two plates are usually made of the same material, though they may be of two different materials.

Polarity—The terms positive and negative are employed to designate the direction of the flow of current to or from the battery; that is, the positive plate is the one from which the current flows on discharge, and the negative plate is the one into which current flows on discharge. In a lead battery the positive plate, on which the lead peroxide is formed, has a comparatively hard surface of a reddish-brown or chocolate color, while the

negative plate, which carries the sponge lead, has a much softer surface of a grayish color.

Electrolyte—The electrolyte used with the lead type of battery is always a diluted solution of sulphuric acid. The specific gravity of the electrolyte when the battery is fully charged, varies from about 1.210 for stationary batteries to 1.300 for automobile ignition batteries and other portable batteries.

The proper specific gravity to use varies with the conditions, and the specific gravity may be found by the use of a hydrometer. When the cells of the battery are fully charged, the specific gravity of the electrolyte, as indicated by the hydrometer, should be 1,275 to 1,300 at 70 degrees F. The final density is the usual practice. None but sulphur or brimstone acid should be used. When diluting, the acid should be poured into the water slowly and with great caution.

Never Pour the Water Into the Acid—The specific gravity of commercial sulphuric acid is 1.835, and 1 part of such acid should be mixed with 5 parts (by volume) of pure water. Care should be taken that no impurities enter the mixture. The vessel used for the mixing must be a lead-lined tank or one of wood that has never contained any other acid; a wooden washtub or spirits barrel answers very well. The electrolyte when placed in the cell should come ½ inch above the top of the plates. Before putting the electrolyte in the cells, the positive pole of each cell should be connected to the negative pole of the next cell in the series and the whole battery of cells should be connected, through a main switch, to the charging source—the positive pole of the battery to the positive side of the charging source, and the negative pole of the negative side. After adding the electrolyte the battery should be charged at once or at least inside of 2 hours. A little pure water should be added occasionally to the electrolyte to make up for evaporation,

and a small quantity of acid should be added about once a year to make up for that thrown off in the form of spray or that absorbed by the sediment in the cells. Do not use anything but pure distilled water in storage batteries because any impurities such as those commonly found in tap or well water will in a very short time absolutely ruin the battery.

Test of Specific Gravity—The specific gravity of the electrolyte is the most accurate guide as to the state of charge of a lead type storage battery. The test of the specific gravity is made by means of a hydrometer having a suitable scale for the type of cell to be tested. In all portable types of batteries, and ordinarily in vehicle batteries it is usually necessary to draw some of the electrolyte from the cell in order to test its specific gravity with the hydrometer, which should have a scale reading from 1,150 to 1,300.

Charging—The normal charging rate is the same as the 8-hour discharge rate specified by manufacturers. The charge should be continued uninterruptedly until complete; but if repeatedly carried beyond the full-charge point, unnecessary waste of energy, a waste of acid through spraying, a rapid accumulation of sediment, and a shortened life of the plates will result. At the end of the first charge, it is advisable to discharge the battery about one-half, and then immediately recharge it. It is advisable to overcharge the batteries slightly about once a week, in order that the prolonged gassing may thoroughly stir up the electrolyte and also to correct inequalities in the voltages of the cells. If the discharge rate is very low, or if the battery is seldom used, it should be given a freshening charge weekly.

Indications of a Complete Charge—A complete charge should be from 12 to 15 per cent greater in ampere-hours than the preceding discharge. The prin-

cipal indications of a complete charge are: (1) The voltage reaches a maximum value of 2.4 to 2.7 per cell, and the specific gravity of the electrolyte a maximum of 1,275 to 1,300 per cell. If all the cells are in good condition and the charging current is constant, maximum voltage and specific gravity are reached when there is no further increase for ¼ to ½ hour; (2) the amount of gas given off at the plates increases and the electrolyte assumes a milky appearance, or is said to boil.

Voltage Required—The voltage at the end of a charge depends on the age of the plates, the temperature of the electrolyte, and the rate of charging; at normal rate of charge and at normal temperature, the voltage at the end of the charge of a newly installed battery will be 2.5 volts per cell or higher; as the age of the battery increases, the point at which it will be fully charged is gradually lowered and may drop as low as 2.4 volts. All voltage readings are taken with the current flowing; readings taken with the battery on open circuit are of little value and are frequently misleading. After the completion of a charge and when the current is off, the voltage per cell will drop rapidly to 2.05 volts and remain there for some time while the battery is on open circuit. When the discharge is started, there will be a further drop to 2 volts, or slightly less, after which the decrease will be slow. Cells should never be charged at the maximum rate except in cases of emergency.

Direction of Current—The charging current must always flow through the battery from the positive pole to the negative pole. If it is necessary to test the polarity of the line wires when no instruments are available, attach two wires to the mains, connect some resistance in series to limit the current, and dip the free ends of the wires into a glass of acidulated water, keeping the ends about 1 inch apart. Bubbles are given off most freely from the negative end.

Discharging—Heavy overcharging rates maintained for a considerable time, are almost sure to injure the cells. The normal discharge rate should not be exceeded except in case of emergency. The amount of charge remaining available at any time can be determined from voltage and specific-gravity readings. During the greater part of a complete discharge, the drop in voltage is slight and very gradual; but near the end the falling off becomes much more marked. Under no circumstances should a battery ever be discharged below 1.7 volts per cell, and in ordinary service it is advisable to stop the discharge at 1.75 or 1.8 volts. If a reserve is to be kept in the battery for use in case of emergency, the discharge must be stopped at a correspondingly higher voltage. The fall in density of the electrolyte is in direct proportion to the ampere-hours taken out, and is therefore a reliable guide as to the amount of discharge.

Restoring Weakened Cells—There are several methods of restoring cells that have become low: (1) Overcharge the whole battery until the low cells are brought up to the proper point, being careful not to damage other cells in the battery; (2) cut the low cells out of circuit during one or two discharges and in again during charge; (3) give the defective cells an individual charge. Before putting a cell that has been defective into service again, care should be taken to see that all the signs of a full charge are present.

Sediment in Cells—During service, small particles drop from the plates and accumulate on the bottom of the cells. This sediment should be carefully watched, especially under the middle plates, where is accumulates most rapidly, and should never be allowed to touch the bottom of the plates and thus short-circuit them. If there is any free space at the end of the cells, the sediment can be raked from under the plates and then scooped up with a wooden ladle or other nonmetallic device. If

this method is impracticable, the electrolyte, after the battery has been fully charged, should be drawn off into clean containing vessels; the cells should then be thoroughly washed with water until all the sediment is removed, and the electrolyte should be replaced at once before the plates have had a chance to become dry. In addition to the electrolyte withdrawn, new electrolyte must be added to fill the space left by the removal of the sediment; the new electrolyte should be of 1.3 or 1.4 sp. gr. in order to counteract the effect of the water absorbed by the plates while being washed. If at any time any impurities, especially any metal other than lead or any acid other than sulphuric acid, gets into a cell, the electrolyte should be emptied at once and the cells thoroughly washed and filled with pure electrolyte.

Idle Batteries—If a battery is to be idle for, say 6 months or more, it is usually best to withdraw the electrolyte, as follows: After giving a complete charge, siphon or pump the electrolyte into convenient receptacles, preferably carboys that have previously been cleaned and have never been used for any other kind of acid. As each cell is emptied, immediately refill it with water; when all the cells are filled, begin discharging and continue until the voltage falls to or below 1 volt per cell at normal load, and then draw off the water.

Putting Battery into Commission—To put an idle battery in commission, first make sure that the connections are right for charging; then remove the water, put in the electrolyte, and begin charging at once at the normal rate. From 25 to 30 hours continuous charging will be required to give a complete charge.

Sulphating—Lead sulphate is practically an insulator. Some of this material is formed in all lead-sulphuric-acid storage cells on discharge and is reconverted to lead oxide or lead peroxide on recharging the cell. If present in excessive quantities, the sulphate adheres to the plates,

especially the positive, in white soluble patches, preventing chemical action, increasing the resistance of the cell, and causing unequal mechanical stresses that may buckle the plates. The most frequent causes of sulphating are overdischarging, too high specific gravity of electrolyte, and allowing the battery to stand for a considerable length of time in a discharged condition.

GENERATORS

Methods for Locating and Repairing Break in the Armature of Generator—A break in an armature must be located by the fall of potential method, which means that a current must be sent through the armature and the voltage tested across the various segments. First disconnect all the leads from the armature and lift all brushes except one on each pole, then connect the battery to these brushes through the resistance and ammeter shown in Fig. 30, connect the detector to one brush, and then to each segment in turn with a wire from the other terminal of detector until the break is located.

If the two wires from the detector are connected to the segments that the brushes are standing on, a deflection will be seen caused by a fall of voltage through the coils. If we gradually draw the movable wire over the segments towards the other brush, the deflection will gradually fall to zero, providing it is on the side on which the break does not occur (Fig. 30). If, however, the wire is drawn over the segments on the other side, the deflection on the instrument will remain constant until the failing segment is reached, when the deflection will drop to zero as the wire passes over the break.

Instead of moving the testing wire around the commutator, a course that might not always be convenient, it could be held stationary against the commutator, say a few segments from one of the brushes, and the armature gradually pulled around till the break appeared.

In this case on the unbroken side a constant deflection will be obtained till the break passes a brush, when the

needle will fall to zero. On the other side there will be no deflection till the break passes one of the brushes. So long as the break is between the movable testing wire and the brushes to which the detector is connected,

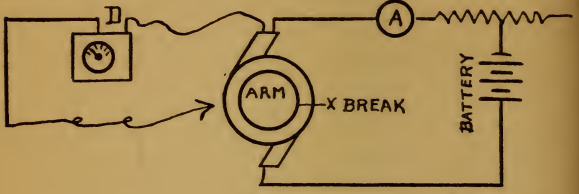


FIG. 30

there is a deflection; but not when the break is between the fire brushes and the testing wire. If the instrument gives a good reading between two adjoining segments, it will show a much larger reading across a break.

If a millivoltmeter is available, the matter is somewhat simplified, as a small current is sufficient for testing, such for instance as the current taken by an incandescent lamp. If, therefore, the armature be connected to a source of supply through a lamp, a millivoltmeter will give a good deflection across a break. Millivoltmeter is the instrument used as a shunted ammeter in conjunction with various law resistances called shunts; when used as a millivoltmeter in the manner above described, it is used alone, the armature itself taking the place of the shunt (Fig. 31).

Having found the broken section it must be examined till the actual break is discovered. In the case of a winding, the bad section can be taken out and a new one put in without much difficulty. In the case of a formed wound drum, it is generally an inaccessible bottom wire that breaks. In this case it is usual to strip

the armature till the break is reached; this is not always necessary. Having found the defective section, cut out as much as can be got at, that is the conductors on the surface of the core or in the slots. Leave the end crossing wires in, but with the ends separated and rewind the section with the end crossings on top of the others.

Overheating the Armature—Several causes will cause overheating of the armature, the most common being—overload, grounds, eddy currents in the core, eddy currents in the conductors, short-circuit in the coils, sparking at the commutator, heat conducted from the bearings, low insulation. If the excessive heating is uniform over the whole armature, the machine is overloaded.

Should one or two of the coils be overheated, the trouble is due to a short circuit in the winding. If the core is hotter than the coils, the trouble is due to excessive eddy currents in the laminations, caused by the core rubbing up against one of the pole faces, or it may be caused by a number of the laminations being short-circuited, the slots having been filed too much when

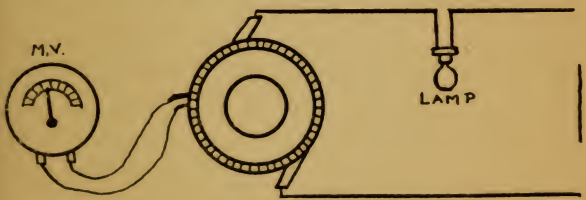


FIG. 31

the core was built. Heating due to eddy currents either in the armature core of the conductors, cannot be remedied by the projectionist, the maker of the machine should be immediately notified. The test is to run the

generator on open circuit and take note of the rise in temperature. To test for a ground in the windings, first disconnect the generator from the circuit, and then run it up to normal speed. Using an ordinary test lamp, touch the opposite brushes to make sure you have the voltage.

Then connect the lamp terminals between the generator frame and the poles. Should there be a ground the test lamp will either glow or light. The cause of the ground should then be located and removed.

Locating Ground Coil—To locate a grounded coil is a difficult job, and should not be undertaken by anyone who is not familiar with electrical apparatus.

The armature should be removed from the field and set on trestle, a current (not to exceed the normal current of the dynamo) should be passed through the armature from any one of the commutator segments to the shaft. A compass should be held near the conductors, and the needle will be deflected in a certain direction due to the flow of current. If the armature is slowly turned round, till such time as the compass needle reverses, this will indicate the proximity of the grounded coil.

Low insulance (insulation resistance) between the core and the armature winding, is generally caused by the presence of moisture, and often accompanied by vapor arising from the armature. This can be remedied by baking the armature in an oven at a temperature of about 200° F, or by running the machine unloaded for a few hours and sending a small current round the windings.

The short circuiting of the coils is generally accompanied by heavy sparking and a smell of burning may be caused by copper dust, oil on bits of solder lodged between the commutator arms.

Locating Short-circuited Coil—To locate a short-cir-

cuited coil, use the same method to locate break in armature. It is best to test between each pair of segments, remembering that the readings will all be alike when connected across the good coils, and that a variation in the reading points to a fault.

The remedy for a short circuited coil is to strip the damaged parts and rewind.

A temporary repair job can be accomplished by disconnecting the short circuited coil from the commutator arms, and then bridging the arms, thus cutting out the defective coil.

Should the short circuiting of the coil be due to copper dust, oil, etc., between the commutator arms, all that will be necessary will be to dislodge the foreign substance.

When a generator is overloaded, the temperature of the armature will rise, and heavy sparking of the brushes will also result. If the machine is run without removing the overload, the insulation of the armature may be destroyed.

Overheated Bearings—A hot bearing may result from one or more of the following causes: Insufficient lubrication, faulty lubrication, grit or other foreign matter in the bearings; armature not centered with respect to pole pieces; side pull due to magnetic pull on armature; end pressure of collar against the bearing—due to machine being out of line, with its driving shaft, or to want of alignment in engine; to a bent armature shaft; shaft rough or cut, etc., etc.

Only the best of oil, free from sediment and grit, should be used for lubrication, the ordinary machine oil supplied and used on the projector is too thin for this class of work, all the oil cups should be kept clean and filled, the oil rings should be watched to see that they carry the oil up to the shaft.

When the heating of a bearing is due to the presence

of dirt or grit, it should be cleaned with some thin oil or kerosene. If kerosene is used, do not forget to use a good lubricant directly after the cleansing.

The bearing caps should just be tight enough to run freely, without any side play. If a bearing is too tight the oil cannot get through as the oil passage remains full. The same thing occurs if the oil passages become choked with dirt or grit.

Do not tighten up the bearing caps with pliers, as sufficient pressure can be brought to bear with the finger and thumb. After tightening up the caps the armature should revolve freely, and when in motion the armature should come gradually to rest. Should the armature stop quickly the bearings are too tight.

A bent shaft will cause the armature to rub pole pieces, and thus produce sparking, vibration and overheating. To overcome this it will be necessary to remove the armature from the machine and have the shaft straightened in what manner is most handy. It may be found necessary to withdraw the shaft from armature before this can be accomplished.

A rough shaft may be caused by dirt, grit or overheating. The roughness, if not excessive, can be taken out by the use of a little emery cloth, but care should be taken to remove all grit and filings when the job is finished. If the roughness is so great that it cannot be taken out with the use of emery cloth, it will be necessary to remove the armature, and smooth up the shaft in a lathe, using a very fine file and emery cloth.

Noise in a generator can be laid to one of the following causes: Bent or broken shaft; armature out of balance; brushes grinding commentator; armature hitting pole pieces; loose bearings. All screws and bolts should be periodically gone over and any loose one tightened. If the noise is due to the armature not being properly balanced, the makers of the machine should be

notified, as this is due to faulty construction of the generator.

A grinding or squeaking noise from the brushes can sometimes be stopped by the application of a very little vaseline to the commutator. If, however, the noise continues, the brushes should be removed and examined to see that a "hard place" has not developed. Should this be the case, the brushes should be filed down past the "hard place" and then replaced in the holders.

In the event of a short-circuit a fuse would naturally blow, and all generators should be fused up as near the terminals as possible.

A series-wound generator would spark and pull the engine up. It would not give any current to the arc.

A compound-wound generator would spark and show a drop in voltage.

A shunt-wound generator would lose its field and would not excite till such time as the short was removed.

MOTORS

SPARKING may be due to overload, wrong position of brushes, broken coil, weak field, and to any of the causes named for dynamos.

SPARKING

Symptom—Intermittent Sparking. On a varying load, in which the work comes on, at the beginning or end of each cycle, and then falls off during the remainder of the cycle, a motor often sparks just as the peak load comes on.

The cause is the heavy current taken at the instant of maximum load, which distorts and weakens the effective field and shifts the neutral point. This weakening of the field results in a still larger current in the armature, aggravating the evil.

Remedy—Add a compounding coil on the motor to assist the shunt, or exchange the motor for a compound-wound one, or one with interpoles.

FAILURE TO START

(1) *Symptoms*—Motor does not start. Little or no current passes on closing the D.P. switch and pushing starting handle over.

Probable Causes—Brushes not down. Switch not making contact in the jaws. Starting switch not touching the contacts. Fuse Broken. Controller fingers not touching contact plates. Break in series coil (if a series motor). Terminal loose. No current on mains.

If the no-volt release coil excites, or if a long arc is observed on breaking circuit, it indicates that the shunt

field gets its current and the probable cause of the failure to start is that the shunt is connected in series with the armature owing to two of the leads from the starter being reserved.

Remedy—Trace out the connections or use testing set.

FAILURE TO START

(2) *Symptom*—Motor does not start, but takes excessive current. Fuse or overload cut-out acts.

Cause—It is assumed the motor is not overloaded; this can be tested by taking load off and trying to start motor light. If a shunt motor there may be a short circuit in connecting cables or in field coil; or in armature; or a break in field coil.

Remedy for broken field. If field excites when brushes are up, but not when they are down, the symptoms point to a short circuit in or across armature, or brushes.

Examine brushes for short circuit to frame, for copper dust, oil, or broken down insulation.

Then disconnect armature and excite field. Move armature round quickly by hand. A drag will be felt as the short circuited coils pass the poles. If the armature can be driven at a fair speed by belt, with the field excited, the short-circuited coils will warm up and can probably be located in this way.

If the above symptoms occur with a series-wound motor, the cause may be a short in the field or armature, but not a break.

A fairly common cause is incorrect connecting up.

Another cause, particularly with machines that have been dismantled, is incorrect polarity of the field coils. Thus if the coils are connected up so that they are all of the same polarity, the effect is the same as with a broken field wire as the field is completely neutralized. If only one of the field coils is reversed in a four-pole

motor, the motor would probably not start and would in any case take an excessive current.

Remedy—Test the coils for polarity.

Incorrect Speed—A certain amount of speed adjustment may be obtained by altering the position of the brushes. Moving the brushes backwards from the neutral point has the effect of increasing the speed, while moving them forward reduces the speed.

EXCESSIVE SPEED

Symptom—Motor starts, then speed gradually increases till motor runs at very excessive speed. This only occurs when a motor starts light or on a very light load such as a loose pulley.

Cause—If shunt or compound motor. Shunt coil connected in *series* with armature instead of in parallel.

On first switching on, the magnets excite, as the armature is stationary and allows the full shunt current to pass the coils. As the armature speeds up it puts a back E.M.F. in the circuit, gradually reducing the current passing and thus weakening the field. The faster the armature goes the weaker the field becomes. A short circuit in the shunt might produce same result if motor starts absolutely light.

Remedy—Connect up the shunt.

FUSE BLOWS

Symptom—Motor starts and runs up to its proper speed, but fuse or overload acts on putting load on.

Cause—This is a sign of overload. Probably belts too tight, bearings tight or dry.

If the fuse blows while starting up there may be a ground on the motor. This should be tested. If the starter is provided with shunt sector the fuse may blow while starting up, owing to a bad contact to this sector, due either to dirt or to a hollow place in the metal.

In the case of a compound-wound motor a cross connection or leakage between the series and shunt windings will cause the fuse to blow if the cross is in a position that the shunt is practically short circuited by the series.

STARTER OVERHEATS

Symptom—Motor starting against load takes excessive current. Last few coils of resistance overheat (probably smoke or get red hot). Fuse or overload acts, or motor sparks.

Cause—Overload; or starter too small.

When a motor starts against a load having considerable inertia, such as heavy line shaft with several large pulleys and tight belts, or against a heavily fly-wheeled machine, time must be given for it to get up speed. If the starter is moved over the contacts more quickly than the motor can accelerate, an excessive current will pass, causing the motor to spark. The starter must be put on more slowly and this will cause it to heat up unless it has been liberally rated.

Remedy—Exchange starter for one having more margin, that is one which permits of starting up slower. This does not mean a starter for a larger H.P.

STARTS SUDDENLY

Symptom—Motor does not start nor take current till most of resistance is cut out, then takes rush of current and starts suddenly.

Cause—A break in the starting resistance.

Temporary Remedy—Connect the contacts where break occurs, until resistance can be repaired.

WRONG DIRECTION

Symptom—Motor runs in wrong direction.

Remedy—Reverse armature or field connections, whichever is the easier, but not both.

In a compound-wound machine both the shunt and series coil must be reversed if the field be reversed; but if the machine be provided with interpoles these must be treated as part of the armature and must therefore not be reversed when the field is reversed.

MOTOR REVERSES

Symptom—Motor starts up and runs correctly on light load. On an overload, or reduced voltage, motor reverses and runs backwards.

Cause—This applies to a compound-wound motor, with the series or compound coil connected up in opposition to the shunt coil.

Remedy—Reverse the series coil.

FLASHING

Symptom—Severe sparking or flashing apparently all round the commutator; overheating of the armature and burning of the insulation between a couple of the segments.

Cause—The cause of the above is a broken wire in the armature winding.

Remedy—If the broken end cannot be located and repaired easily, the armature must be stripped until the break is found and the section re-wound. A temporary repair can sometimes be made sufficiently to enable the motor to continue working, by joining across the two segments on each side of the burnt mica with a short piece of copper wire, the wire being laid on the ears of the commutator and sweated in with a soldering iron. This practically converts two segments into one, and the motor will run in this way quite satisfactorily. If the commutator lugs are not readily accessible, a copper pin may be driven hard down between the two segments in a part not under the brushes.

FLASHING OVER

Symptom—On an overload and sometimes on a normal load a motor will flash from the brushes to a part of the commutator or to the rocker, and blow the fuses. This is more liable to happen with a weak field.

Cause and Remedy—The cause is that the motor has too much forward lead, and the brushes should be moved back a little.

SOUND EQUIPMENT INSPECTION ROUTINE

A STUDY of the service calls that have come into the Cleveland Local Service Department on sound equipment shows some unexpected results. Equipments which are rugularly inspected by the projectionist for the purpose of service engineers' reports to the manufacturers rarely call for special service for anything other than breakdowns in equipment that could have been foreseen and forestalled.

On equipments where this regular inspection is not made necessary by the manufacturer, fully two thirds of the calls for assistance are for troubles that a careful inspection would have disclosed before they had reached the point where the show was stopped or quality impaired.

This can mean but one thing—every installation of sound equipment must be inspected regularly and systematically by those in charge of it. Such an inspection can only be successful if it follows a definite routine. If a regular chart is followed it finally becomes second nature to watch for the things indicated, but if no regular routine is followed then many things are missed until something happens. All the technical information in the world is not going to help put the show on if the equipment is not kept in condition.

This prompted Victor Welman to prepare the following chart for members of the Cleveland Chapter of the American Projection Society.

Inspection Chart—A chart is given below suggesting

a routine which, if followed in inspection, would eliminate much trouble. There is scarcely an item in this entire chart which cannot be pointed out as the basis of a trouble call in some of our houses.

Pick-Up

Film,
- Coupling resistors.
- Filament and exciting lamp rheostats.
- Exciting lamp (focus, filament, blackness).
- Slit assembly (oil, focus, alignment).
- P. E. C. (position, lead).
- Amplifier suspension cradle free.
- Oil in amplifier or cable.
- Switch clicks.
- Film batteries and fuses.

Disc,
- Drift in reproducer.
- Reproducer, (noisy, low volume, needle holders).

Fader,
- Clean.
- Operates normally.

Switching Panels,
- Contacts (clean, function properly).
- Relays.
- Signal Lamps.

Amplifier

Gain Control (clean).
Transformers (heating).
Filter condensers (clean—normal appearance).
Snap switches, keys, packs.
Sockets (contacts clean, tight).
"C" batteries, (voltage, age).
Meter readings.
Fuses.

Tubes, (matched, contacts clean).
Socket mountings.

Power Supply

Batteries,
  Electrolyte level.
  Specific gravity.
  Clean.
  Connections (tight, greased, clean).
  Battery log.
Charging Panel and Charger,
  Fusing.
  Switches.
  Charging rate.
  Functions normally.
  Connections tight.
Motor Generator and Converter,
  Brushes and commutator.
  Overheating and vibration.
  Lubrication.

Mechanical

Lubricants and lubricating interval.
Chain tension.
Motor flywheel (tight alignment).
Motors, (alignment, vibration).
Drives and gear boxes (heating, grinds, alignment).
Rubber connectors.
Set screws.
Couplings.
Film Sprockets.
Stripper plates.
Tension shoes.
Guide rollers, (condition, adjustment).
Turntable level.

Wiring

Connections (soldering, tight).
General condition.
Ground connection (clean, greased).
Conduit (well fastened).

Motors

Commutators.
Brushes, (clean, seating properly).
Speed—acceleration.
Fuses.

Spare Parts

List of parts needed.
See that these parts are on hand.

A uniform and complete routine followed out every day in starting the equipment and preparing to start the show will head off many of our troubles. Here is a suggestion as to a routine which only takes a few minutes yet is fairly complete.

Suggested Starting Routine

1. Batteries checked.
2. Apparatus cleaned.
3. Exciting lamps checked, (focus and condition).
4. Oiling and greasing.
5. Testing system and horns.
6. Testing motors and mechanisms.

PLANNING THE PROJECTION ROOM

THE following recommendations have been adopted, after an exhaustive study, by the entire projection practise committee of the S.M.P.E. and are submitted for adoption as standards. In following them the local code should in all cases be consulted for deviations from these standards. It is the aim of the Committee to bring them before the various agencies for revision and adoption. Three layouts have been adopted, marked A, B, and C, which were planned for flexibility, simplified construction, ease of operation, *etc.*, to be selected according to the size of theater and type of operation.

(1) *Projector Spacing*—The distance between projectors shall be not less than 4½ feet nor more than 5 feet, measured between lens centers; for projection distances less than 100 feet, the spacing shall be 4 feet. When two projectors are used, they shall be equally spaced on either side of the center line of the auditorium. When three projectors are used, the center projector shall be placed on the center line of the auditorium.

(2) *Observation Ports*—Observation ports shall be 12 inches wide and 14 inches high and the distance from the floor to the bottom of the openings shall be 48 inches. The bottom of the opening shall be splayed 15 degrees downward. In cases where the thickness of the projection room wall exceeds 12 inches, each side shall be splayed 15 degrees.

(3) *Projector Ports*—Projector ports shall be 10 inches wide and 12 inches high. The bottom and sides of the openings shall be splayed in the same manner as observation ports. The distance from the floor to the

bottom of the openings shall be in accordance with the table of projection angles as given in the plans for the layout of the projection room.

(4) *Other Openings*—All other openings, such as those intended for effect projectors, double dissolvers or single spot lamps shall be 24 inches wide and 34 inches high. The distance from the floor to the bottom of the openings shall be 26 inches when the angle of projection is not greater than 20 degrees. For projection angles greater than 20 degrees, one inch shall be deducted from this value for each degree in excess of 20. The minimum spacing allowed between these openings shall be as shown on the plans for the projection room layout. The placing of these openings to the right or left of the projectors shall be optional and according to conditions.

(5) *Dimensions of Projection Room*—The projection room shall have a minimum height of 10 feet and a maximum of 12 feet. The minimum depth of the room shall be 12 feet. The length of the projection room shall be governed by the amount and type of equipment, as shown on the plans. Consideration should always be given for probable future needs.

(6) *Front Wall*—In all cases, the inside surface of the front wall of the projection room shall be smooth and without structural projections. Care shall be exercised in locating the hanging rods and columns in the front wall so as not to interfere with the proper location of the various openings.

(7) *Conduits*—These shall in all cases be concealed, and all boxes shall be of the flush-mounting type.

(8) *Projection Arc Conduit*—The size of conduits for projection arcs shall be as indicated on the plans. These sizes anticipate the need for future increased capacity, and should be adhered to in order to provide space for pulling in larger wires as needed.

(9) *Conduit for Sound Equipment*—Conduit for sound

equipment shall conform with the type of sound equipment to be installed. The manufacturers of such equipment should be consulted with regard to the proper layout of the sound system before proceeding with the installation.

(10) *Projection Room Lighting*—An individual ceiling fixture with canopy switch shall be installed for each piece of equipment, and shall be placed in line parallel to the front wall at a distance not less than 18 inches or more than 24 inches from the front wall. The outlet connected to the emergency lighting system shall be located in the ceiling midway between the extreme ends of the projection room, and 4 feet from the back wall. Small projection rooms shall be equipped with one reel light and large projection rooms with 2 such lights conveniently located.

(11) *Ventilation*—A separate exhaust system of ample capacity shall be provided for the projection room and other adjacent rooms provided for projection equipment. All projection arcs, and arcs of other equipment as required, shall be connected into the ducts of the exhaust system, which should contain a blower type exhaust fan. There should also be a gravity vent in the main projection room, rheostat room, generator room, and sound equipment room, leading directly through the roof. The minimum size shall be 12 by 18 inches, maximum size 18 by 24 inches. They shall also be equipped with swivel cowls. A supply of fresh air shall be brought into the projection room, preferably at the floor level and at the extreme ends of the room, and shall be baffled to prevent direct drafts. In cases where the theater is equipped with a refrigerating system, the projection room system should be connected into the main duct of this system. A fan shall be provided of sufficient capacity to remove all smoke and gas in case of fire, and this fan should be so connected to the port shutter controls that its full

capacity will be automatically made available upon dropping of the shutters.

(12) *Extra Rooms*—A separate room shall be provided solely for the rheostat equipment. This room shall be provided with ventilating means as previously set forth. An additional and separate room, properly ventilated, shall be provided for the sound equipment.

(13) *Toilet and Wash Room*—Hot and cold water and other toilet facilities shall be installed and located convenient to the projection room. Suitable space shall also be provided for clothes lockers.

(14) *D-C. Supply for Arcs*—Two generators or other sources of direct current shall be installed to insure continuous operation in case of breakdown.

(15) *Location of Arc Generators*—Arc generators may be located in a room adjacent to the projection room, and the responsibility for their maintenance delegated to a projectionist. Where the generators are large, making it necessary to reenforce the structure carrying them, they may be placed in the basement, provided proper maintenance is assured. Where the generators are placed near the projection room, this room shall be soundproofed and the foundation for the generator arranged to thoroughly eliminate the noise and vibration of the generator.

(16) *Projection Port Shutters*—These shall be constructed of not less than 16 gauge iron guides built up of iron flats, 2 inches wide and ⅛ inch thick, with spacers 1 inch wide and ¼ inch thick for the shutter to slide in. The shutter shall be made of not less than 10 gauge iron, provided with leather bumpers on sill at the bottom to take up the shock when the shutter drops. Each port shutter shall be connected to a master rod by a string and ring attached to a pin on a master rod. The master rod is to be fastened securely to the front wall, approximately 18 inches below the ceiling. It should be pro-

vided with a sufficient number of bearings properly aligned to assure smooth operation, connected through pulleys and fusible links located over each projector and capable of being controlled at the exit so that it may instantly be tripped. All large openings in addition to the above shall be provided with an individual approved counterweight which will permit the shutters to be easily opened and shall be controlled by the master rod. All observation ports shall be provided with metal guides to receive ¼-inch clear glass, this glass to be at an angle opposite to the projection angle and arranged to be easily removed for cleaning.

(17) *Projection Room Painting*—A sufficient number of coats of paint shall be applied to assure a good coverage. Walls and doors shall be painted an olive green to the height of the door line. The walls above this line and the ceiling shall be painted buff. All painted surfaces shall be stippled to prevent reflections. All iron work on projection ports shall be covered with 2 coats of flat black paint. All other rooms shall be painted buff.

(18) *Projection Room Floor Covering*—The floor of the projection room shall be covered with a good grade of "battleship" linoleum (brown or green) or rubber tile securely glued down. The floor covering should be laid before the equipment is installed. The floors of rooms adjacent to the projection room should be painted with a good grade of concrete paint.

(19) *Fire Extinguisher Equipment*—The local fire department or safety commission should be consulted regarding the proper type, amount, and location of fire extinguishing equipment. In all cases there shall be adequate provision of such equipment.

(20) *Projection Room Construction*—(*a*) The projection room shall be of fire-proof construction, and all walls exposed to the theater shall be of tile brick, gypsum, or any approved fire-resisting material. The walls

of the projection room shall be not less than 6 inches thick and shall be covered inside and outside with a layer of plaster at least ¾ inch thick. The inside walls and ceiling of the projection room shall be coated with an approved sound absorbing plaster. Projector ports should be blocked down after the projector is set to as small an opening as possible.

(*b*) The ceiling shall be of plaster or concrete suspended on metal lath, and the floor slab should be not less than 4 inches thick, having a 2-inch cinder fill above, and a 2-inch cement finish above the cinder fill.

(*c*) The walls of rooms adjacent to the projection room shall be not less than 4 inches thick, plastered inside and outside. Two exits shall be provided, one at each end of the projection room, in addition to stairways for entering the projection room. Under no circumstances may ladders be used for the projection room entrances.

(*d*) The doors shall be of the approved metal type, swinging outwardly from the projection room, and shall be provided with door checks or other approved door-closing devices.

(21) *Heating*—Proper provisions shall be made for heating the projection room. The same facilities used for heating the theater should be extended to the projection room.

FUNDAMENTAL ELECTRICAL LAWS

Helmholtz's Law—It was discovered in the early days of electrical research that pulsatory currents of either polarity, or currents which alternate in polarity, do not have a value strictly in accordance with Ohm's law. Helmholtz, the great German physicist, interpreted Ohm's law in a form which takes into consideration the element of "time," and from this evolved a formula which gives the true current value in a circuit of any character at any given instant after an e.m.f. has been applied to it.

Where the interruptions in a direct-current circuit, or the alternations in an alternating-current circuit are less than 10 per second, a determination practically agreeing with Ohm's law is obtained; but if the time element is reduced or the value of L (inductance) increased, a point is soon reached where the simpler law would not give a true indication of the conditions obtaining in the circuit.

Lenz's Law—In the year 1834, Lenz stated that "in all cases of electromagnetic induction the induced currents have such a direction that their reaction tends to stop the motion which produces them." To understand what is meant by this, one has but to consider the case of a solenoid into the core space of which a bar magnet may be inserted and withdrawn at will. If the terminals of the solenoid be connected to a sufficiently sensitive galvanometer it may be observed that a momentary current flows through the winding of the solenoid while the magnet is being pushed into the coil, and that as the magnet is rapidly withdrawn a momentary current flows through the winding in the reverse direction to that

which flowed when the magnet was inserted. The more rapidly the magnet is inserted and withdrawn the stronger will be the induced currents. When the magnet is inserted into the solenoid, the resulting induced current is in a direction which tends to magnetize the moving core (the permanent magnet) oppositely to that of its existing polarity. This current, therefore, is an inverse current, while the current induced by withdrawing the magnet is a direct current, tending to pull the magnet back into the coil.

This law has a quite general application in electrical operations, and the example given is but one illustration of its effects.

Boyle's Law—While Boyle's law has not, directly, anything to do with electric circuits, being more often encountered it works dealing with pneumatics and gases; nevertheless, it is frequently referred to in connection with high-frequency electrical phenomena, and has especial significance in those operations employing partial vacua.

In its essence this law states that "the elasticity of the air is inversely proportional to its volume, that being inversely proportional to the pressure upon the air, both heat and pressure increasing the elasticity of a gas."

Poynting's Law—In deductions made from Maxwell's equations in 1883, Professor Poynting concluded that "at any point in the magnetic field of conductors conveying currents the energy moves perpendicularly to the plane containing the lines of electric force and the lines of magnetic force, and the amount crossing a unit of area of this plane per second is equal to the product of the intensities of the two forces multiplied by the sine of the angle between them and divided by 12.5664."

This law has a very wide application in all problems relating to telephony, telegraphy, and electric power transmission.

The Seebeck Effect—In the year 1822, Seebeck discovered that "if bars of two metals (bismuth and antimony) were soldered at their ends and the junctions brought to different temperatures, an electric current flowed round the circuit, flowing through the junction from bismuth to antimony." If the free ends of the two metals are connected in circuit with a sensitive galvanometer, it may be observed that the strength of current is proportional to the difference of temperature at the junction. Currents of electricity produced in this manner are commonly called thermo-electric currents, and the force producing them is called thermoelectromotive-force.

The Peltier Effect—Peltier's discovery, made in 1834, has been stated in the following words: "If a current of electricity from a primary battery, or other source of direct-current, be sent through a junction of several metals, heat is absorbed at some junctions, and emitted at others; the emission and absorption being reversed by reversing the direction of the current; the quantities of these thermal actions being proportional to the current strength."

It is important not to confuse the phenomena of the Peltier effect with the ordinary heating of a metallic conductor offering resistance (the latter is sometimes called the Joule effect), as the cause of the heat in each case is quite different. An electric current passing through a thermocouple in a direction from bismuth to antimony absorbs heat, thereby tending to lower the temperature of the junction; while, when the current flows in a direction from antimony to bismuth the effect of the current is to produce heat, resulting in raising the temperature of the junction. It will be recalled by most students that the heating of a continuous metallic conductor takes place regardless of the direction of current

through it, and that the heat produced is proportional to the square of the current flowing.

The Thomson Effect—Lord Kelvin (Sir William Thomson) found a somewhat similar effect to the Peltier discovery, when any one metal is used but different parts of the metal kept at different temperatures.

Kirchoff's Laws—Kirchoff's laws are elaborations of the well-known laws of joint resistance, by the use of which it is possible to investigate the current in each branch of any network of linear conductors.

"In any branching network of wires the algebraic sum of the currents in all the wires that meet in any point is zero."

"When there are several electromotive-forces acting at different points of a circuit, the total electromotive-force round the circuit is equal to the sum of the resistances of its separate parts multiplied each into the strength of the current that flows through it."

By means of algebraic equations, assigning arbitrary values to the potential of each junction, except two, at which state potentials are applied from a source of e.m.f., all problems of divided circuits and networks may be solved by correctly interpreting these laws.

Bosscha's Laws—Bosscha published the following corollaries from the laws of divided circuits, established by his predecessors. In general, they may be regarded as simplications of Kirchoff's laws, and are stated as follows:

First—If in any system of circuits containing any electromotive-forces there is a conductor in which the current=O, the currents in the remaining circuits are not altered, if the circuit of the conductor in question is taken away together with the electromotive-force which is contained in it.

Second—If the conductor in question contains no electromotive-force at all, then after it has been withdrawn

we may connect the terminal points *m* and *n* directly with each other, without changing by this means the remaining currents. If, on the contrary, it contains an electromotive-force, the points can only be joined again by inserting between them the equivalent electromotive-force.

Third—In a system of linear conductors there are two wires *a* and *b,* in which an electromotive-force in *a* produces no current at *b,* then the wire *a* may be divided without changing the intensity at *b,* and likewise, without altering the intensity at *a,* the wire *b* may be divided.

The Barkhausen Effect—While experimenting with vacuum tube amplifiers in 1919, a German physicist, Barkhausen, discovered that under certain conditions a peculiar crackling noise was heard in the telephone receiver connected in the output circuit of the amplifier. Whenever the magnet was moved in the vicinity of the iron core, the sound was noticeable. After repeated experiments he concluded that changes of magnetization in the iron did not proceed uniformly but in definite small and uniform steps; that a minute portion of the core would suddenly change its magnetization and after a very brief interval another change would occur, and so on.

Hall Effect and May Effect—In the May effect is noted the variation in the electrical resistance of selenium, according with variations in the intensity of light impressed upon it.

The Hall effect notes the resistance of metals, particularly bismuth and bellurium, varying with varying applied magnetic field intensities.

Faraday Effect—Faraday discovered that plane polarized light can be twisted so that the light vibrations are in a different plane.

Kerr Effect—Kerr discovered that a ray of polarized light is rotated when the ray is reflected from the polished surface of a magnet, finding that it makes a dif-

ference in the direction of rotation which pole of the magnet reflects the light beam.

Kundt Effect—It was Kundt's discovery that when a thin film of iron (transparent) is mounted transversely in a magnetic field, a beam of plane polarized light passing through it will have its plane of polarization rotated.

INTERESTING FACTS AND INFORMATION

THE average speed of sound in air is 1,100 feet a second.

Light travels at a speed of 186,000 miles per second.

The primary powers are, water power, wind power, tide power, power of combustion and power of vital action.

That light is reflected according to two laws—a, the angle of reflection is equal to the angle of incidence. b, the incident and the reflected rays are both in the same plane which is perpendicular to the reflecting surface.

Gun metal is nine parts copper, one part tin.

The first motion picture story was filmed in 1903.

Radio frequencies run as high as 1,500,000 cycles per second.

An element is an original form of matter that cannot be divided into constituents by any known process.

One horse power (electrical) is equal to 746 watts.

The human ear will not respond to sounds below 20 cycles or above 20,000 cycles.

Electro-magnetic waves travel at the same rate of speed as light, 186,000 miles per second.

There is no such thing as a direct current.

Kinemacolor was first shown in London in 1908.

A 100 cycle note has a wave length of eleven feet.

Sound was first recorded on wax in 1889, by Emil Berliner.

Thomas Edison built the first motion picture studio in 1893.

The resistance of the human body measured from hand to hand varies from 3,000 to 15,000 ohms.

Brass is made of seven parts copper and three parts zinc.

Boiling point is 100 degrees, freezing point 0 degrees (Centigrade).

Boiling point is 212 degrees, freezing point 32 degrees (Fahrenheit).

There is no such thing as a motion picture, we are deceived into the belief of motion, due to a defect of the human eye known as persistance of vision.

A centimeter is equal to 0.3937 inches.

The characteristics of sound are—Pitch, Loudness, Quality.

Chloride gas has a specific gravity of 1.4.

We could never have had motion pictures if a cow did not eat mustard.

The first colored film was made in 1895. It was hand colored.

That electric current runs from Negative to Positive, and not from positive to negative as is generally stated in text books.

That a battery does not store electricity.

That there are approximately 20,000,000,000 electrons in a tiny globe of copper having a diameter of 100,000 part of one inch.

That there are about 75 known elements.

That all space and matter is filled with "ether."

The first film exchange was opened in 1894.

That D. W. Griffiths Birth of a Nation made over 1,000,000 dollars profit.

Light always travels in a straight line.

Light cannot be stored or transported in storage.

Lumiere Brothers of France were the first to use a 16 per second rate for projecting motion pictures. (1894) They also coined the word "cinema."

The first projector with an intermittent movement was made by Thomas Amet in 1896. He got the idea from a geneva watch movement and a bicycle.

Selenium melts between 217 and 220 degrees, its specific gravity is 4.788.

A circular mil is the unit of area. The area of a circle whose diameter is one mil.

The ohm is the unit of electrical resistance. The ohm is that amount of resistance offered by a column of pure mercury, 106.3 centimeters in length by one square millimeter in cross section at a temperature of zero centigrade.

Latham's projector the Pantoptikon, was the first projector to be equipped with reels for film.

The primary colors are, red, yellow and blue.

That light is refracted whenever it passes obliquely from one medium to another of different optical density.

The first sound was recorded on a piece of smoked paper.

That Edison is credited with being the first to record and reproduce sound (1877). The sound was recorded on tin-foil.

That everything in an electrical circuit offers resistance to the flow of current.

The first recording of sound vibrations was made by M. L. Scott in 1857.

Selenium was discovered by Berzelius in 1817, was first thought to be a metal.

That specific gravity is the density of a solution against that of another, using water as a standard.

The reflected rays of concave spherical mirrors do not meet exactly at the same point. (Spherical aberration.)

That stereoscopic motion pictures were shown in New York in 1922. (Teleview. Placticon.) Both systems used some manually operated device to obtain the third dimension.

Technicolor was first shown on Broadway, N. Y., in November, 1922. (Toll of the Sea.)

That thorium is used in the coating of filaments of vacuum tubes.

The Audion tube was introduced by DeForest in 1905.

Motion pictures were first projected in this country by Edison in 1896.

The joint resistance of two conductors connected in parallel is equal to the product of the resistances, divided by their sum.

To find length of throw needed to obtain a certain size picture, multiply required picture dimensions by focal length of lens and divide by slide or film dimensions.

Resistance of any conductor is equal to its length in feet divided by the area in circular mils, multiplied by the resistance per mil foot which is 10.8.

The heating of a rheostat is proportional to the square of the current it carries.

Resistance of insulating material and carbon decreases with an increase of temperature.

The joint resistance of any number of resistances connected in parallel is the reciprocal of the sum of the reciprocals. The reciprocal of a number is 1 divided by that number.

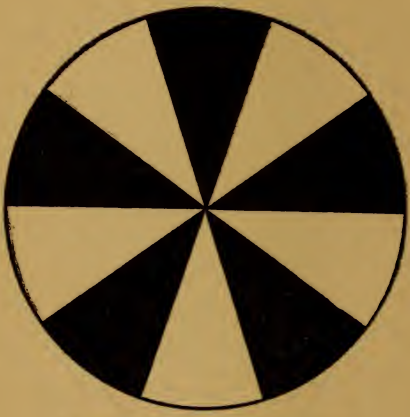
Resistance of all metals increases with an increase of temperature.

A Simple Projector Speed Indicator—When using a disc or film attachment on a projector it is necessary to keep the speed constant at 90 feet per minute. Some machines are so built that the speed cannot be changed, but there are many which have provision for speed control. For these some sort of a speed indicator is necessary. A speedometer will cost about $15. The indicator here described does the work and costs practically nothing.

A Victor phonograph speed indicator is made up of a

disc of white cardboard upon which is printed 92 black lines or spokes. When illuminated by a 60-cycle lamp the lines stand still only if the turntable is going at 78 r.p.m.

Applying this to the disc turntable we need 216 lines or spokes. This is too many for easy drawing. The



Cardboard disc for home made speed indicator.

FIG. 40

only other easily accessible revolving part on a Simplex projector is the shutter shaft. The shutter revolves once for each picture projected. Since 24 frames per second are shown the shutter shaft turns at 1440 r.p.m. For this speed only five lines are required.

A circle, say 12 inches in diameter, is cut from a disc of white cardboard. With a protractor lay off divisions of exactly 36 degrees each. Radii are drawn through

these marks. With a black paint each alternate space is blocked out. The drawing shows how the disc looks when completed.

A method of fastening the disc rigidly to the shutter shaft must be devised. The writer used the knob from one of the controls of an old Mazda lamphouse. This knob was in two parts, held together with three screws. The disc fitted nicely between the two parts of the knob.

A 60-cycle lamp must be used to light the disc. It will not work with any other frequency or on d-c. If a lamp with heavy filaments is used it will not go "bright" and "dim" operated on a-c.

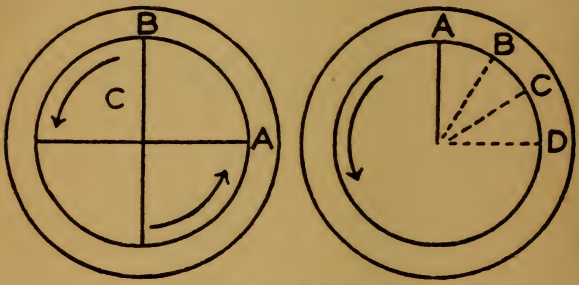
A very small lamp is best. Better results could be obtained with one of the small neon lamps, which cost about 75 cents.

In use the disc is clamped on the shutter shaft, so that the "pie" segments can be seen. A light is thrown on the disc. With the machine turned on, the speed is varied until the lines appear to stand still. If the lines appear to go in the same direction as the rotation the speed is too high. If the lines go in the opposite direction the speed is too slow.

It might be desirable to have the speed indicator running all of the time. The disc could be mounted on a shaft inside a box fastened to the wall of the booth. A hole about two inches square would show the disc, which would be illuminated by a neon lamp inside the box. A flexible shaft would be used to connect the shutter shaft and shaft on which the disc turns.

The Reason Automobile Wheels Turn Backward on the Screen—Of course you all know that "moving pictures" don't really move, but are just a series of individual snap shots showing the successive positions of moving objects. But it is just these successive positions which may easly produce the illusion of "wheels turning backward," which quite naturally are going in the right

direction. This fact can be illustrated by the diagram (Fig. 41) of four-spoked wheels rotating at such a speed that after one picture of the film has been exposed the spoke "A" has turned around just enough to show "A" at the position of "B" when the next picture is exposed. It is then quite evident that in a case of this kind, if the spoke and camera keep turning at constant speeds, when the picture is projected upon the screen it will appear to be standing perfectly still.



FIGS. 41-42

Again, the wheels on fast-moving cars often appear as if they were moving backward. This would happen if the spoke "A" had been revolving so fast when it was photographed that the interval between one exposure and the next the wheel revolved all the way around from "A" to "B" (Fig. 42). When the next successive exposure was made the spoke appeared at "C," and so on.

When this film is projected on the screen the spokes will seem to run backward. No matter how many spokes there are in the wheel, it is evident that the effect on each one will remain the same, and the entire wheel will

appear to turn backward at the same speed as that of each spoke.

The so-called mystery is nothing more than an optical illusion. How can this be avoided?

Several ways. If one must show an automobile being driven across the screen in a film, try and select one with disc or wire wheels. Or shoot the car from the front or rear in such a position that the wheels do not show on the screen. Or let them turn as they may!

Dont's for Projectionists—Don't allow water or any dampness to penetrate the rheostat or motor.

Don't fail to keep the commutator and brushes on the motor perfectly clean.

Don't neglect the arc lamp connections. High amperage eventually chars the asbestos lead nearest the lamp and efficiency requires that a new connection be made every week.

Don't use oil or grease on lamp joints or rods. Use a little powdered graphite at the joints.

Don't allow carbon dust or other dirt to accumulate in the lamphouse. A small pair of hand bellows will readily blow out all the dust.

Don't expect good results with dirty or pitted carbon jaws.

Don't remove pins from intermittent sprocket without proper support for sprocket.

Don't, in W.E. equipment, have the PEC coil too tight or too slack—both conditions are bad.

Don't let oil accumulate in the PEC compartment. Swab out with rags and be more sparing with the oil can. Don't try to alter the bill without unlocking the clamp in a U-Base.

Don't let flexible couplings run out of true even if they will stand it.

Don't cuss the second when he's late with the dowser.

Fit a chain device of some sort and let one man do the job.

Don't run with a warped disc. Use the standby or, if pressed, lay the faulty one flat in the sun or in a hot room which should cure it.

Don't try to undo a "buck" hexagon grub screw with the end of a file. Keep the special wrench in your pocket.

Don't operate switches in other than the sequence specified. To protect the equipment from damage, the sequence of operation of switches specified in the Operating Instructions must not be deviated from.

Don't oil oilless bearings. Oiling instructions are given for all parts of the equipment. These instructions should be rigidly adhered to, both as to the frequency of oiling and the quantity required. To neglect to do so may result in a failure of the equipment to function. Oil should not be applied to parts that do not require it. The bearings of tension pulleys used in the drive of 206-type reproducers are of the oilless type. Oil on these bearings causes them to stick, with the result that the equipment becomes inoperative.

Don't neglect to keep apparatus clean. The successful operation of the equipment depends on its being kept clean and in good running order. Excess oil and grease must be carefully wiped off. Dust and dirt must be wiped off the tops of batteries, so that a short circuit path will not develop. Emulsion must not be allowed to accumulate on sprockets, idlers, or film tracks, but must be carefully removed by wiping with a cloth and not scraping with a knife.

To scrape off emulsion with a knife may injure the surface over which the film must run, resulting in scratched film. The film itself must be kept free of oil, dust, dirt and fingerprints to get the best possible quality of reproduction.

Don't operate projector with mechanism doors open.

Don't start the projector until threading has been checked up.

Don't lift the fire shutter when the film is in magazine and lamphouse douser is open.

Don't start the projector until the picture is in frame.

Don't use force in driving pins or removing shafts.

In removing intermittent sprocket be careful not to strike it against sides of mechanism.

Don't have too much tension on pad or film guide. This causes undue wear on the star wheel and intermittent sprocket, and may injure the film.

Don't let film trap door slam after threading as the film may be thrown off sprocket and ruined when projector starts. Place finger against film trap door and let it close easily.

Don't use steel to scrape the emulsion off the film trap and tension springs. Use edges of a coin or piece of copper or other soft metal.

Don't force your projector when it seems stiff. It may need oil or an obstruction may have found its way into the working parts.

Don't thread film carelessly. In order to have perfect synchronization the various loops specified in the operating instructions must be strictly adhered to in threading the film, both in the projector head and in the sound reproducer. Improper threading may result in film damage and a show interruption.

Don't allow poor quality of reproduction. As soon as it is evident that the quality of reproduction is poor, endeavor to locate and clear the cause immediately. When the projectionist cannot locate and clear the trouble, the Service Engineer should be notified, so that the condition may be remedied as soon as possible. When the quality is poor the condition may be made somewhat less conspicuous by decreasing the volume when normal

volume is not necessary for the audience to follow the picture.

Don't forget that a single universal joint can *never* turn easily. Two will if the angles with the main shafts are equal.

Don't forget flexible shafts sometimes require lubrication.

Don't tie a flexible shaft in knots. Give it a fair chance.

Don't cut off any wire. Unsolder it—you may be glad of a spare inch later on.

Don't bare wire ends with cutting pliers or a pocket knife. Pull off the rubber with needle nosed pliers which will not damage the wire or scrape off the tin.

Don't say resin flux is too slow and use spirit.

Don't examine storage cells with a lighted match—your eyes are valuable.

Don't forget to clean the soldering iron after you have used it for greasing accumulator lugs.

Don't re-mark a projector without checking the turntable if your machines are U-Base type.

Don't switch quickly on to "Plate" even if tubes seem to stand it.

Don't interchange rectifier and amplifier tubes.

Don't use a "recovered" photo-cell.

Don't test out horn type receiver without horns.

Don't assume the stage horns are O.K. when the monitor is working.

Don't close the motor switch before pulling round for one-half turntable revolution when on disc.

Don't wear a long trailing overall.

Don't clean contacts with carbon tetrachloride—it may eventually corrode them.

Don't forget to turn down the exciter lamps after a show—the batteries will probably be recharged between times.

Don't fix lamps within 4 feet of sound unit.

Don't return an exciter lamp until it burns out. Renew when it starts blackening or the filament sags slightly.

Don't alter the position of the lens tube in the sound unit.

Don't expect pre-focussed separate exciter lamps to align perfectly when they are shot home. Readjust after the reel is cleared.

Don't forget a little graphite grease often stops a noisy resistance.

Don't forget that any loose metal object near the PEC compartment may introduce crackle.

Don't experiment with the equipment. The life of the equipment will almost certainly be shortened, and inferior quality will result, if the equipment is experimented with, or operated in a manner different from that specified in our operating instructions. Both design and operating instructions are based on long and wide experience with this class of equipment, and there is, therefore, practically no likelihood that anything will be gained by changes, unless made after careful study by those thoroughly familiar with the theory, design, and manufacture of the equipment.

Don't use unauthorized parts. Such parts of the equipment as are subject to wear and deterioration with use may need replacing. A stock of the spare parts supplied or recommended by us should therefore be maintained by the theater for replacement use. These spare parts should be carefully stored and marked, and their use and placement thoroughly understood, so that replacements can be made with a minimum loss of time in emergencies.

To use unauthorized parts may result in inferior reproduction and unsatisfactory operation of the equipment, or in permanent damage to it. As spare parts are used up, others should be ordered to take their places and maintain the stock. All the component parts of the

equipment are specifically designed for the use made of them, and to get the best results from this equipment it must be operated in accordance with the requirements that determined its design.

Don't grouse about surface noise when there is machine noise.

Don't use cheap needles or try experiments with "permanents." "Loud tones" are best.

Don't get oil on a disc.

Don't clamp needles too tight or you may throw the pickup out of adjustment.

Don't forget that reproducer "drift" is almost as important as correct tracking.

Don't blame recording for flutter before you have checked shaft alignment and damping arrangements.

Don't omit to test the reed type pickups for equal tuning. Tap the needle both sides and check the "plop" for volume and pitch.

Don't forget to replace burned out pilot lamps. Some day you may have need of them.

Don't neglect equipment. Inspect the equipment and observe at all times whether it is normal. Set screws that have become loose must be tightened. If any misalignment exists it must be remedied. Overheating of rheostats and overheating of equipment are indicative of faults that must be remedied to insure the proper running of a show.

Don't attempt delicate intermittent repairs without proper tools.

Don't adjust take-up tension spring too tightly. Too much tension wears sprockets and damages film.

Don't run projector with magazine doors open.

Don't allow cold air draught from fan or other sources to blow into lamphouse. Such draught will invariably result in condenser breakage.

Don't screw up condenser rings and holder tightly.

Don't fail to wash sprocket teeth at least twice a week with stiff bristled tooth brush dipped in kerosene.

Don't fail to keep aperture plate clean.

Don't fail to close lamphouse douser if film breaks.

Don't fail to match "O" marks when replacing gears.

Don't fail to remove oil box complete when adjusting intermittent sprocket.

Don't fail to keep pad rollers adjusted to two thicknesses of film.

Don't bend the intermittent guide open. To do so will cause serious film damage.

Don't forget to oil the take-up spindle.

Don't fail to oil the pad rollers.

Don't fail to see that all pad rollers are turning when machine is in action.

Don't fail to keep rollers in upper and lower magazine roller holders clean and well lubricated.

Don't expect an amplifier to be dead as soon as the mains are pulled. Condensers remain charged and a 1,000 volt kick is painful.

Don't test for a started condenser with a 6 volt buzzer. It is useless nine times out of ten.

Don't omit to correct output levels when replacing a PEC.

Don't smack a dud PEC near water—some types explode.

Don't search for echoes in the auditorium with the ports open.

Don't forget that heavy drapes near the screen will cut off the top and leave the boom.

Don't forget to set the shutter after removing the intermittent case from the mechanism.

Don't use alcohol, benzine, kerosene or turpentine as a lubricant. Simplex oil is the only lubricant recommended.

Don't fail to give mechanism a kerosene bath at least once a month.

Don't try to put enough oil into mechanism at one oiling to last a week; use less oil and use it oftener.

Don't forget any of the oil holes. They are there for a purpose and every one of them is important. Locate each of them on the instruction plates.

Don't fail to oil machine every time before using, particularly the intermittent movement.

Don't put vaseline, grease or packing of any kind into the intermittent casing.

Don't fail to keep lenses and condensers clean at all times.

Don't use a rough cloth or waste to clean optical units. A piece of chamois, linen or soft cloth moistened with ammonia will given the best results, and remove all dirt as well as giving a high polish. Use equal parts of ammonia and water.

Don't fail to examine all electrical connections on lamp, rheostat or motor. For any electrical device to be efficient all connections must be firmly tightened.

Don't use misadjusted, defective or deteriorated equipment—Any equipment that gives any indication of being in any way abnormal must be replaced or brought to the attention of the Service Engineer. The focus of the exciting lamp must be exact, for the reproduction depends upon the intensity of the illumination on the film track. If a filament in the exciting lamp sags or is not straight, or if the inside of the glass becomes coated with a black deposit, it should be changed. Vacuum tubes showing bright spots on the filaments or otherwise abnormal should be replaced to avoid failure during an exhibition.

Don't ignore meter readings. The various meter readings are given in the operating instruction book. When the meter readings differ from these values, or when the

meter readings cannot be adjusted to the value specified, location and remedy of the cause may prevent the equipment from failing during a show.

Don't operate tubes at other than specified current values. The operating instructions fully describe the current values at which tubes should be operated. To deviate from these by running at lower than specified values may result in insufficient volume or poor quality of reproduction. To operate at values greater than those specified greatly reduces the life of the tubes.

Don't install fuses of sizes other than specified. To install a fuse of a lower capacity than that required may result in an unwarranted interruption of the show, due to the fuse burning out under conditions that would not cause the proper size fuse to blow out. To use fuses of greater than specified capacity will not adequately protect the equipment, and may result in permanent damage to the equipment when abnormal conditions exist and a fuse does not blow out to protect the equipment.

Don't flare a buzzer near the sound unit or you may get pickup of an unwanted nature.

Don't tighten motor brushes to stop sticking before examining the commutator for dirt.

Don't forget electric motors generally want end float. Set couplings to allow for this.

Don't test tube emissions before everything is properly warmed up.

Don't think a reduced filament current is economy.

Don't forget too low value cartridge fuses sometimes have a higher resistance which upsets meter readings.

Don't forget if a grounded wire breaks you can always pick up from earth.

Don't store "B" batteries. They deteriorate with time whether they are used or not.

Don't forget an oily lens or PEC window cuts off top.

Don't use the scratch filter to the sacrifice of clarity.

Don't forget that condensers may be shopped out for the time being.

Don't forget there is no such thing as a cheap, dependable resistor.

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